DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-77-42

AQUATIC DISPOSAL FIELD INVESTIGATIONS ASHTABULA RIVER DISPOSAL SITE, OHIO

EVALUATIVE SUMMARY

by

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June 1978
Final Report

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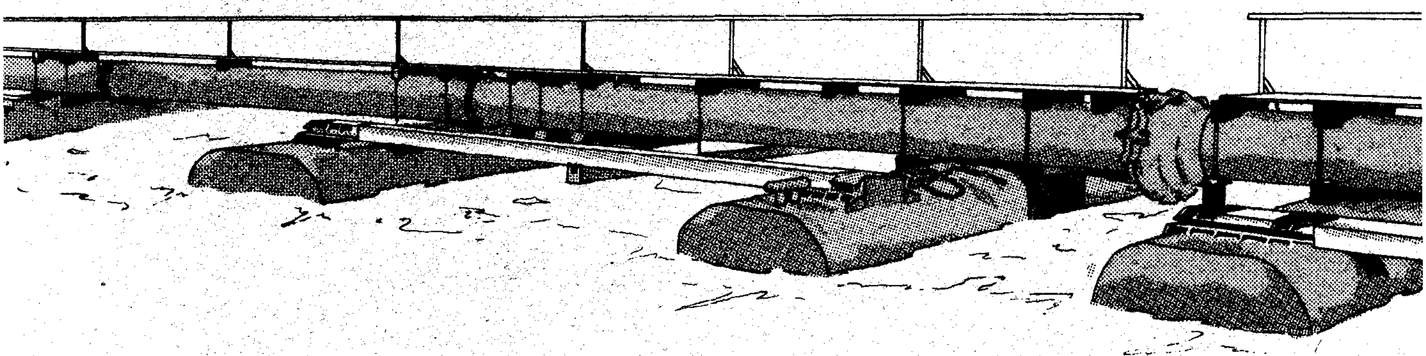

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AQUATIC DISPOSAL FIELD INVESTIGATIONS,
ASHTABULA RIVER DISPOSAL SITE,
OHIO

Appendix A: Planktonic Communities, Benthic Assemblages, and Fishery

Appendix B: Investigation of the Hydraulic Regime and Physical Nature of Bottom Sedimentation

Appendix C: Investigation of Water-Quality and Sediment Parameters

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Errata Sheet

No. 1

AQUATIC DISPOSAL FIELD INVESTIGATIONS

ASHTABULA RIVER DISPOSAL SITE, OHIO

Evaluative Summary

Technical Report D-77-42

June 1978

The following sentences were inadvertently omitted from the Preface, page vii, and should be added to the end of the second paragraph:

> The WES Site Manager for the Ashtabula study was Dr. James Seelye, formerly of the Environmental Monitoring and Assessment Branch of EL. Dr. Seelye is currently on the staff of the U. S. Fish and Wildlife Service Laboratory at Ann Arbor, Michigan.

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15 July 1978

SUBJECT: Transmittal of Technical Report D-77-42

TO: All Report Recipients

1. The technical report transmitted herewith contains a summary of the results of several research efforts (work units) undertaken as part of Task 1A, Aquatic Disposal Field Investigations, of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 1A was part of the Environmental Impacts and Criteria Development Project, which had as a general objective evaluation of the effects of open-water disposal on biota and water quality at selected disposal areas. This report is a summary of the physical, chemical, and biological studies that were conducted at the Ashtabula River disposal site, Ohio. This research site was one of five studied under the DMRP in various geographical regions of the United States.

2. This report, Aquatic Disposal Field Investigations, Ashtabula River Disposal Site, Ohio; Evaluative Summary, presents an overview of the various research efforts conducted at the Ashtabula site. Three contractor-prepared reports form Appendices A-C to this report, the titles of which are listed on the inside front cover. This report provides additional interpretations and conclusions not found in the appendices and, in addition, provides a comprehensive summary and synthesis of the entire study.

3. The purpose of the Ashtabula study was to determine the physical, chemical, and biological effects of open-lake disposal of dredged material in the area adjacent to the entrance to the Ashtabula River. In addition, this study involved the detailed monitoring of two dredged material disposal events, the estimation of the short-term impacts of the disposal of dredged material, and the subsequent recolonization of the affected sites. Data indicate that disposal of dredged material produced short-lived impacts in the water column, including the phytoplankton and zooplankton communities. Benthic impacts, as well as physical and chemical sediment alterations, were produced; however, predisposal conditions generally were reestablished within a year following disposal.

4. Conclusions of this report, based on the data presented, are that while disposal effects were indicated in the benthic communities and in the sediments, these effects generally were transient in nature. In addition, there was no indication of accelerated uptake of heavy metals by fish or benthos as a direct result of disposal.

5. Results of this research will be useful in a regional sense for evaluating the possible environmental impacts of open-water disposal in the lacustrine environment of Lake Erie. These studies will be helpful in planning dredging and disposal projects involving open-lake disposal so as to minimize adverse environmental effects.

John L. Cannon

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

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Environmental effects	Waste disposal sites

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An investigation to evaluate impacts of the release of dredged material on chemical and physical aspects of the aquatic and benthic environments as well as phytoplankton, zooplankton, benthos, and fish was conducted in Lake Erie off Ashtabula, Ohio, from June 1975 through September 1976. Samples and measurements were taken prior to, during, and after the release of materials from a hopper dredge during August 1975 and May 1976.

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20. ABSTRACT (Continued).

The impacts on the water column including the phytoplankton and zooplankton communities were short-lived. While the benthos as well as the chemical and physical nature of the sediments were altered, predisposal conditions generally were reestablished within a year after the release of the dredged material. Storm event related erosion of the dredged material appeared to be a major factor in the recovery of the area. There was no evidence of accelerated uptake of heavy metals by fish or benthos as a consequence of disposal. Harbor macroinvertebrates, transported with the dredged materials, did become established in the deposition area. With the exception of the latter, the observed impacts were similar to those noted in studies to evaluate the impact of dredged materials on the marine environment.

THE CONTENTS OF THIS REPORT ARE NOT TO BE USED FOR ADVERTISING, PUBLICATION, OR PROMOTIONAL PURPOSES. CITATION OF TRADE NAMES DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS.

SUMMARY

Physical Aspects

1. Bathymetry measurements within the Disposal Area indicated that the maximum thickness of the sediment piles resulting from the disposal operation was < 0.5 m and, in most cases, could not be accurately measured with standard acoustic methods. The survey rods and sediment traps proved to be the most effective methods to measure the sediment accumulation. The results of three measurements indicated that approximately 70% of the disposed material fell within the study areas. Some of this material was removed from the study area within three months due to resuspension and subsequent transport from the area. The currents were the main source of energy for sediment transport as most of the wave energy did not penetrate to the bottom.

2. The currents in the Disposal Area generally flowed parallel to the shore with average speeds of 12 cm per sec at 3 m above the bottom and 5 cm per sec at 1 m above the bottom. The dominant periodic component of the velocity field was the first longitudinal mode of Lake Erie, which had a period of 14 hrs. The currents, at times, were uniform over the entire study area and changes in the local winds usually did not immediately affect the established flow pattern. The wave field, however, was directly influenced by the local wind. The waves were usually < 1 m but increased to > 2 m during storms. The latter events accounted for the bulk of the sediment transport, which primarily occurred in a northeasterly direction.

3. Analysis of sediment cores revealed that the disposal operation produced only minor changes in the grain-size distribution of the sediments. These changes, however, were quite transient as these variables generally returned to their predisposal values within three months.

4. The measurements taken during the disposal operation indicated that the actual discharge of material had no lasting effect on the physical aspects of the water column. A temporary temperature increase of 2° C and currents of up to 70 cm per sec were produced near the Disposal Site by the discharged material, but such conditions also occurred naturally in this area. The

transmissivity dropped to zero following the sediment discharge, but it also frequently dropped to zero following a storm. Within an hour after the disposal, the currents, temperature, and transmissivity had virtually returned to their ambient values in the Disposal Area.

5. The measurements taken in the Disposal Area and the subsequent analysis of the data indicate that the disposal of the dredged material has very little effect on the physical nature of the area. The same conclusion was made based on the results from investigations of the impacts of disposal of dredged materials in marine environments (Cronin et al. 1976).

Biological Aspects

6. Pelagic biota (phytoplankton, zooplankton and fish) were only mildly impacted in the area of disposal and recovery was relatively rapid, except possibly in the bottom waters directly influenced by dynamics at the mud-water interface. Similar effects of disposal on fish (Ritchie 1976), phytoplankton (Flemer 1976; Markey and Putnam 1976), and zooplankton (Goodwyn 1970) have been observed in marine environments.

7. The bottom area initially impacted by disposal is very limited and dependent upon the path and surface distance covered by the hopper dredge while disposing of dredged material. With time, however, invasions of communities some distance from the Disposal Sites by foreign species may take place, possibly as a result of unstable community structure.

8. An evaluation of the community structure of dredged material in contrast to the communities being disposed upon is very important. The types of organisms transported to the Disposal Sites within dredged material play a large role in reconstructing the entire bottom community in the vicinity of disposal.

9. Since important components of the life cycle of many species encountered during this study occur at distinct seasonal time intervals that rarely correspond to one another, disposal must be based upon when there would be minimal effects on the fauna directly related to the higher levels of the food web.

10. The biota in freshwater open-lake disposal areas largely recovered as soon as 1 year after disposal, but the community structures may be slightly altered in contrast with predisposal conditions.

11. There was no evidence that uptake of heavy metals by either fish or benthic macroinvertebrates was accelerated by the disposal operations.

Chemical Aspects

12. Deposition of dredged materials in the open-lake environment induced immediate effects on almost all measured parameters in the aquatic environment. Generally, these effects were very short-termed, with a return to ambient predisposal conditions for suspended or particulate constituents within 90 min after disposal. Soluble variables (PO_4-P, NH_3-N, etc.) exhibited that longer periods of time were required to return to the predisposal levels. Rates of return to predisposal conditions were believed to be a function of settling velocities for particulate variables and/or the time needed to carry the dissolved constituents out of the study area via the prevailing currents. Most disposal monitorings exhibited multinodal peaks suggesting an initial release plus secondary water mass movements associated with the turbidity plume. Although the total monitoring effort showed short-lived effects, the fate of the soluble nutrients transported out of the study area was not determined. For reasons based primarily on the design of on-site monitoring, the effects of various dredging or disposal techniques (except for overflow) could not be ascertained. Dredging with overflow produced greater effects on the bottom waters, while dredging without overflow generated more profound surface water effects.

13. Water chemistry results from periods other than the actual disposal monitoring showed only slight short-term effects. Parameters which exhibited a definite effect from disposal were Specific Conductance, soluble SiO_2, TKN, P_T, PO_4-P, and Mn. Parameters that showed some minor effects of disposal included Temperature, DO, pH, Alkalinity, NH_3-N, DOC, POC, Hg, Fe, and Zn.

14. Interface water concentration alterations dissipated usually within a period of time < 5 days after disposal with some residual effects still

evident at 60 days after deposition. The results of discriminant analysis of interface data suggested the transport of sediments via erosion was in a north-northeast direction.

15. Currently employed elutriate test procedures were judged to be of limited value for evaluating the potential release of contaminants from the proposed dredged materials. Comparison of elutriate and on-site monitoring data yielded incompatible results. Those parameters which increased in the elutriate tests did appear in elevated concentrations during disposal monitoring. The reverse, however, was not true. During disposal monitoring all parameters that showed maxima or minima were not evident during the elutriate test results.

16. Interstitial water concentrations were found to be impacted at all Disposal Site stations. However, chemical conditions returned to predisposal levels in a relatively brief period of time (30 to 90 days). It was believed that the rather short-lived effects of deposition on this aspect of the ecosystem were primarily a function of (a) the ability of the interstitial water to reestablish the equilibria present during the predisposal sampling and (b) the erosion and/or compaction of the disposal mound.

17. The benthic environment, as defined by sediment chemistry data, was found to be the most affected geographic component of the study. All areas of the Disposal Sites in 1975 and 1976 were covered to some degree by dredged materials. Generally, the physical and chemical changes in the sediments were a function of erosion and, to a lesser extent, compaction. Return to ambient predisposal levels was seen for some variables by periods of time > 90 days and < 1 year. Other variables, however, remained affected by disposal operations for periods of time > 1 year.

18. SOD rates as a function of disposal operations exhibited significantly higher values (three to five times greater at the Disposal Site compared to the Reference Site) which may or may not be a consideration relative to anoxia problems within the Central Basin of Lake Erie, where oxygen depletions in the hypolimnetic waters have contributed to other problems including the accelerated release of phosphorus from the bottom material. However, with the disposal areas occupying such a small fraction of the total Central Basin bottom region, the Basin-wide impact may have been

very slight. With time, the SOD of the Disposal Sites also approached those of the Reference Sites.

PREFACE

This report presents a summary of the results of a comprehensive investigation of the effects of open-water disposal of dredged material in the lacustrine environment of Lake Erie adjacent to the Ashtabula River, Ohio. This multidisciplinary investigation was conducted between December 1974 and January 1977 as part of the Dredged Material Research Program (DMRP), under Work Unit 1A08. The DMRP was sponsored by the Office, Chief of Engineers, U. S. Army, and was managed by the Environmental Laboratory (EL), of the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi.

This report was prepared by Dr. Robert A. Sweeney, Great Lakes Laboratory, State University College at Buffalo, Buffalo, New York. The Ashtabula study was conducted under the general supervision of Dr. John Harrison, Chief, EL, and Dr. Roger T. Saucier, Special Assistant for Dredged Material Research. Dr. Robert M. Engler was Project Manager.

Directors of WES during the period of this investigation were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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*Published separately

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AQUATIC DISPOSAL FIELD INVESTIGATIONS

ASHTABULA RIVER DISPOSAL SITE, OHIO

EVALUATIVE SUMMARY

PART I: INTRODUCTION

Background

1. The Dredged Material Research Program (DMRP) was initiated in FY 1973 as a four-phase comprehensive program under the River and Harbor Act of 1970 (Public Law 91-611, Section 123). The primary objective of the program was to investigate the environmental impact of dredging and dredged material disposal operations and to develop technically satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives, including the use of dredged material as a manageable resource.

2. An important component of the overall DMRP was research on the effects of dredged material disposal on the biota and water quality within the designated open-water disposal site. This research was part of the Environmental Impact and Criteria Development Project and Task I - Aquatic Disposal Field Investigations (ADFI). This research was conducted at freshwater and marine sites; one such site was offshore from Ashtabula, Ohio, in Lake Erie.

3. Site selection was initiated by an interdisciplinary study team from the U. S. Army Engineer Waterways Experiment Station (WES). The team surveyed numerous sites in the Great Lakes region where there was or had been significant utilization of offshore sites for the disposal of dredged material. Each of these disposal sites was evaluated in terms of the availability of background ecological data for each site and its adjacent area, availability of logistic support for a comprehensive field investigation, and most importantly, characteristics (as defined by the regional survey) that represented the major types of open-water disposal activities within the Great Lakes region. The representative characteristics

included sediment type(s) of dredged material disposed within the offshore environment, chemical characteristics of the material, type(s) of substrate the material is disposed upon, volume of material disposed on an annual basis, frequency of disposal, and depth of water at the disposal site. Based on this evaluation, the Ashtabula offshore disposal site and the area immediately adjacent to that site were selected for the establishment of an open-water disposal field investigation.

4. Offshore disposal of dredged material in the Great Lakes region annually accounts for about 25% (by volume) of all Federally sponsored open-water dredged material disposal within the United States (Printz and Hurst 1975). Table 1 lists the annual volume of dredged material disposal in the Ashtabula region since 1966.

5. Dredging in the Ashtabula area has occurred since at least 1909 (Sweeney et al. 1975). Prior to 1975, almost 4,000,000 m^3 (3,305,974 m^3 of soil and 638,094 m^3 of rock) was removed from the Harbor and River. All of this material was placed at open-lake disposal sites. The 1975 and 1976 dredging activities resulted in the displacement of an additional 240,000 and 87,000 m^3 of sediment, respectively.

Purpose and Objectives

6. The Ashtabula ADFI had three principal overall objectives and other specific objectives as follows:

a. To evaluate the impact of disposal upon the aquatic biological community.

b. To determine chemical (water quality) impact of disposal upon the water column and sediment.

c. To ascertain the movement and eventual fate of dredged material after disposal in the offshore disposal site.

These broad objectives formed the basis for a variety of biological, chemical, and physical tasks which were designated to meet the objectives. The specific tasks were:

Biological

a. To determine the spatial distributions of the natural biological assemblages within the disposal area prior to disposal operations.

TABLE 1

Total Quantities of Dredged Material ($10^5 m^3$) Released within the Ashtabula, Ohio, Region of Lake Erie

Year	Quantity
1966	2.51
1967	1.48
1968	1.48
1969	2.25
1970	1.43
1971	1.08
1972	-
1973	2.55
1974	9.50
Mean	2.23

b. To determine the occurrence and duration of the changes in the composition and abundance of the benthic assemblages after dredged material disposal, with particular emphasis on the colonization of dredged material by benthic organisms.

c. To determine the occurrence and duration of changes in the composition, abundance, and distribution of plankton and fish as a result of disposal operations.

Chemical

a. To determine the concentrations of nutrients, heavy metals, and other chemical parameters in sediments and perform water quality studies on appropriate parameters in the disposal area prior to disposal operations.

b. To determine the dissolved and particulate materials that are released into the water from dredged material and the temporal and spatial extent to which released materials remain above ambient levels during and immediately after disposal.

c. To determine if the disposal of dredged material altered the chemical composition of sediment in the disposal area and, if so, how long such alteration persisted.

d. To determine if there was biological uptake of selected heavy metals by benthic macroinvertebrates and fish in the disposal area.

Physical

a. To determine the bathymetry, sedimentology, and subbottom characteristics of the dredged material disposal site prior to the initiation of disposal activities.

b. To determine the characteristics of the hydraulic regime, including the critical erosion velocities necessary to suspend and transport sediments, current velocities and direction, and amounts of suspended matter in the water column over time after the disposal operation.

c. To determine the natural changes in sediment composition through time.

d. To determine if the dredged material mounds were being eroded through time and, if so, where the material was being transported.

e. To monitor during and after disposal activities to determine the length of time required for ambient conditions to reestablish.

Experimental Design

7. A cursory review of available literature, and discussions with contractors knowledgeable with regard to past investigations in the Ashtabula study area, indicated a deficiency of background data for the study area. Therefore, an extensive (spatial) pilot survey of the study area was initiated. The primary objectives of the survey were:

a. To determine spatial impact of previous disposal operations within the study area.

b. To determine spatial variability of selected environmental parameters within the study area for the selection of experimental Disposal Sites and Reference Sites.

8. The designated Disposal and Reference Areas were divided into 16 and 9 quadrats within their respective 2.56 km^2 areas (Figure 1).

9. Following this initial survey, two clusters of six stations each were established in the Disposal Area. The first group (Stations D1-D6) was positioned at the northeast corner of the area and the second group (Stations D7-D12) was located at the southeast corner of the area. These sites were used for the monitoring of disposal operations of Ashtabula Harbor and River materials, respectively. The Reference Sites were selected at the northwest and southwest corners of the Reference Area. The Reference Sites consisted of two stations at each site (C1, C2, and C3, C4, respectively). During the 1976 sampling, a 400 x 400 m grid of 16 stations (SD1-SD16) was established with its center Northwest Disposal Site (NDS) at the northwest corner of the Disposal Area (Figure 2). Water quality stations (PW1-PW11) were positioned over the entire study area, also as illustrated in Figure 2. Collections from these areas, whether 1975 or 1976 sites, were made for sediment and/or water analyses during predisposal, disposal, and postdisposal time periods.

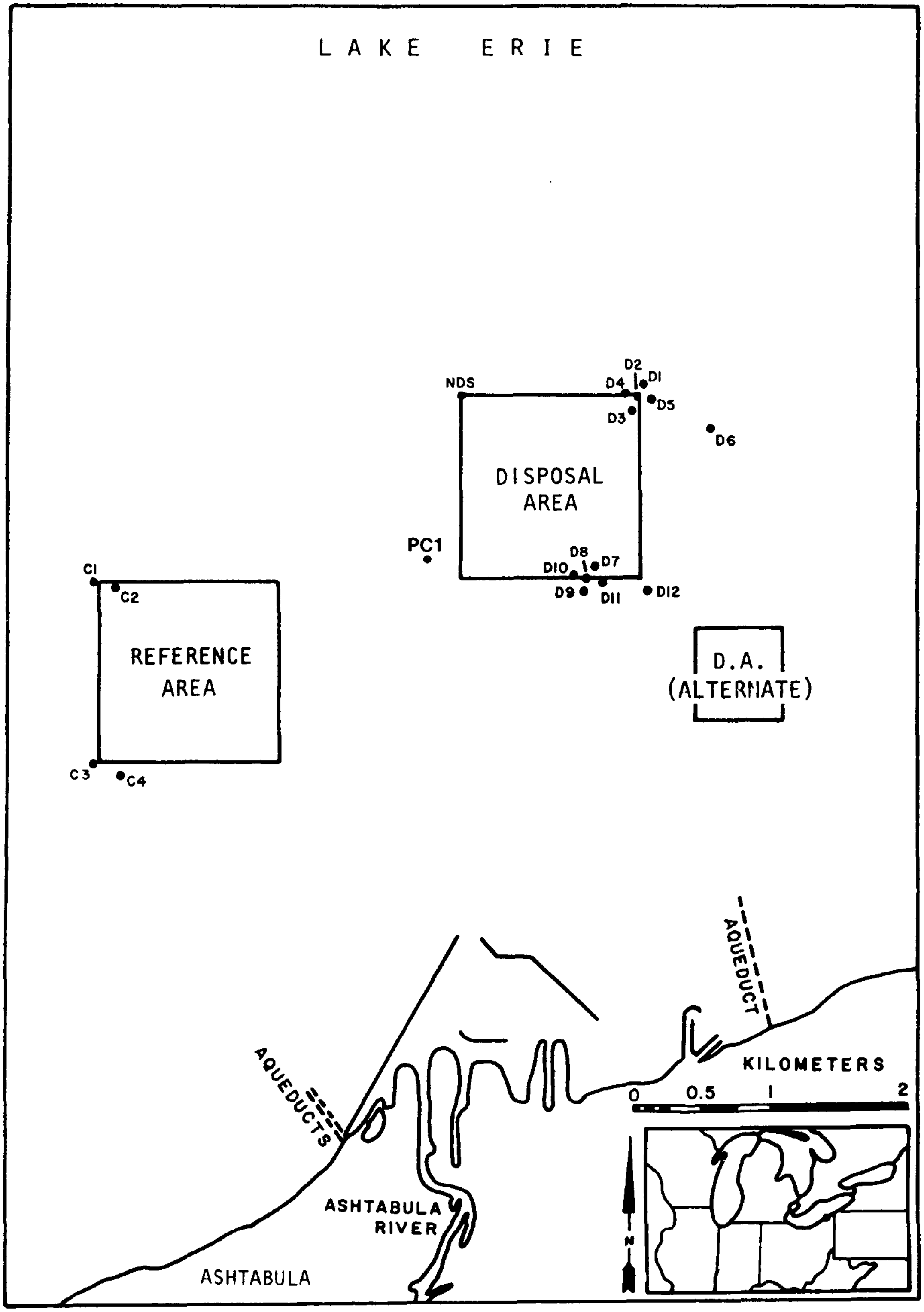


Figure 1. Station locations for reference site stations (C1-C4), current measurement station (PC1), and disposal site stations (D1-D6 and D7-D12) for deposition of Ashtabula Harbor and River dredgings, respectively, during 1975. The northwest disposal site (NDS) was the site of 1976 deposition studies

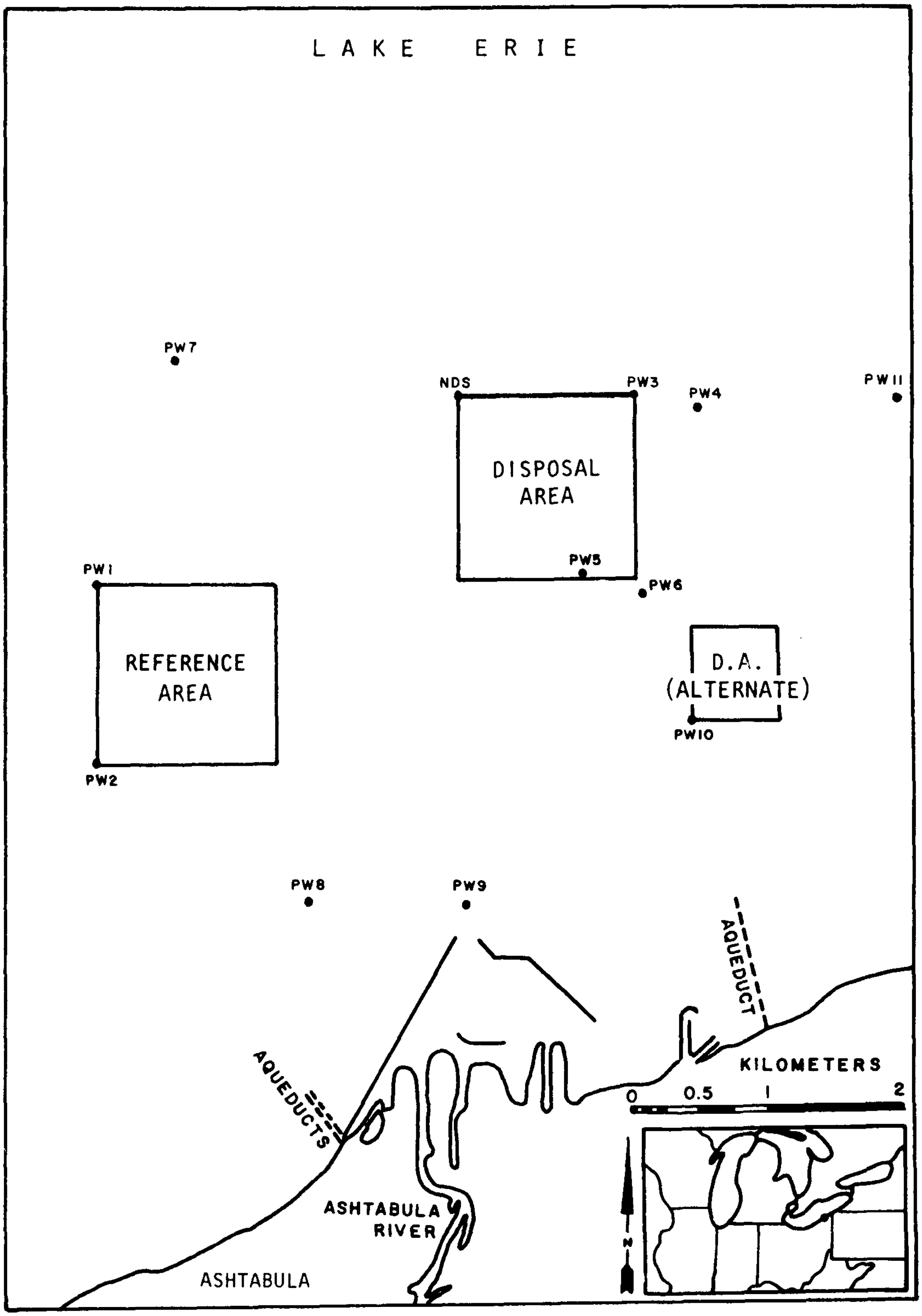


Figure 2. Water quality station locations (PW1-PW11). The northwest disposal site (NDS) was sampled during 1976 only

Chronology of Events

10. From its inception to completion, the Ashtabula ADFI spanned three years. Milestone events are given in Table 2. It can be seen from the table that the project generally was maintained on schedule. However, there were circumstances which were often beyond the control of the participants which resulted in some delays and/or malfunctions. These prevented the complete attainment of a limited number of the project objectives.

TABLE 2

Ashtabula Study
Chronology of Events

December 1974	Request for Proposal's advertising Ashtabula study distributed
January 1975	Site manager selected Request For Proposal's received by WES
February 1975	List of partial contractors prepared
April 1975	Contractor negotiations initiated General scope of work prepared
May 1975	All contracts signed ready for OCE approval
June 1975	Great Lakes Laboratory (GLL) contract for biological and chemical phases initiated NALCO contract for physical phases initiated Initial field surveys conducted
July 1975	Biological, chemical and physical baseline sampling completed
August 1975	Initial disposal and postdisposal sampling
September 1975	30-day postdisposal sampling
October 1975	60-day postdisposal sampling
November 1975	90-day postdisposal sampling
December 1975	Contractor workshop at GLL
March 1976	1975 progress report workshop at WES
April 1976	Contracts modified The 1976 field sampling initiated
May 1976	Contract modifications approved by OCE Second disposal monitored
June 1976	30-day postdisposal sampling
July 1976	60-day postdisposal sampling
August 1976	Contractor workshop at NALCO
September 1976	90-day postdisposal sampling
January 1977	Initial drafts of biological, physical and chemical appendices submitted
May 1977	Final drafts of appendices submitted
January 1978	Initial draft of summary report submitted

PART II: SITE DESCRIPTION

Lake Erie Central Basin

11. The study area is located in the Central Basin of Lake Erie. The Central Basin has an area of approximately 16,317 km^2, as contrasted with 25,667 km^2 for Lake Erie. The Central Basin averages about 18.3 m in depth, with a maximum of 24.4 m. The Lake bottom is generally flat. The Western and Central Basins are separated by a broad, shallowly submerged ridge of sand and gravel which extends south-southwestward from Point Pelee, Ontario, to Lorain, Ohio. The Central and Eastern Basins are separated by a similar ridge extending southward from the base of Long Point, Ontario, to the vicinity immediately west of Presque Isle, Pennsylvania.

12. The predominant surface water movement of Lake Erie is eastward toward the south shore and away from the north shore. This movement is caused by the prevailing southwest winds, but reversals do occur on occasion when the wind direction changes substantially. The predominant flow of the hypolimnetic waters is southwestward to compensate for the eastward surface water flow. Near the south shore of the Lake, however, the entire body of water tends to move eastward, thus retaining any pollutants that are discharged into this area. Pollutants which escape this zone are dispersed within the main body of the Lake.

13. Summer and winter circulations are similar in the Central Basin, except that in the summer the thermocline shifts in depth and location due to seiches. Although it has no net movement, the hypolimnion moves about in the basin, resulting in current velocities at the bottom (up to 0.6 m per second) which are much higher in summer than at other times of the year and capable of resuspending bottom sediments. This phenomenon tends to hasten oxygen depletion in the hypolimnion.

14. Materials suspended in the Central Basin water appear to accumulate on the bottom on the north side of the Lake near the

west end of the Basin as a result of the upwelling of the westward bottom flow, which becomes a large clockwise eddy in that area. Materials not caught in the eastward flow near the south shore can actually cross the Lake when swept up in this flow.

15. Water levels generally do not fluctuate greatly with the wind in the Central Basin. However, prolonged wind from the west or east can cause elevated water levels in the East and West Basin, respectively. Seiches may also cause the Lake level to rise and fall over a period of several hours. Wave activity in the Central Basin during storms often is violent and causes rapid shore erosion. Wave activity also causes faster longshore currents and more rapid and widespread dispersion of contaminants and sediments (Anon 1975).

16. The average or normal elevation of the Lake surface is subject to a consistent seasonal rise and fall. The lowest stages prevail during the winter months, highest stages during the summer months. Between 1969 and 1973, the range of the maximum monthly mean stages has been between 0.92 m and 1.50 m above low-water datum; the range of the minimum monthly mean stages has been between 0.58 m and 0.67 m above low-water datum. At Cleveland, Ohio (approximately 90 km west of Ashtabula), the difference between the highest (174.81 m) and the lowest (172.97 m) monthly mean stages between 1860 and 1974 was 1.84 m. The greatest annual fluctuation, as shown by the highest and lowest monthly means of any year, was 0.84 m, and the least annual fluctuation was 0.27 m. A monthly mean level of 1.04 m above low-water datum occurs with a frequency of once in 20 years.

17. Water temperatures in the Central Basin are essentially uniform from top to bottom, from fall until late spring. In winter the Lake Erie Central Basin is usually covered with ice, although in recent years ice formation has occurred to a lesser degree. From June until September, the Basin is temperature-stratified with a thermocline approximately 15.2 m to 18.3 m below the surface. The thermocline is well defined and separates the epilimnion, with characteristic temperatures above 15.6° C, from the

hypolimnion, where a temperature of 4° C to 5° C is typical. During stratification, the relatively thin layer of cold water on the bottom may lose all of its dissolved oxygen, while the upper layer of warm water remains at or below saturation and occasionally can reach above saturation level. The loss of dissolved oxygen in the hypolimnion is progressive and the minimum is usually recorded late in August or September during the stratification period. The hypolimnion grows thinner when the Lake starts cooling in August, and disappears in late September or early October when the temperature differences disappear. The oxygen-deficient zone disappears as the upper and lower layers of water mix (Anon 1975).

Ashtabula River and Harbor

18. The Ashtabula River extends approximately 28.96 km from the mouth of the River at Lake Erie to the confluence of the East and West Branches. Each branch is 19.31 km long, originating close to the Ohio/Pennsylvania State line; the River itself flows entirely within the State of Ohio. The River watershed is approximately 360 km^2 in area with an average flow of 169 cfs (4.79 m^3/sec), which is 0.08% of the mean tributary discharge to Lake Erie (Anon 1973).

19. Information on flows in the Ashtabula River is provided in Water Resources Data for Ohio (Anon 1973). The data are collected at a gauging station located 8.85 km upstream from the River mouth and also upstream from the city, which monitors a watershed area of 313.39 km^2. Over the complete period of record, average River flows have been as follows:

Average discharge -	146 cfs (4.13 m^3/sec)	
Maximum discharge -	11,600 cfs (328.48 m^3/sec)	22 January 1959
Minimum discharge -	0 cfs	Most years

During the 1975-76 field study, the highest discharges occurred during the winter months with a monthly maximum of 3810 cfs (107.89 m^3/sec) in February 1976. For the June through August 1975 and 1976 periods, the discharge was nearly zero.

20. The City of Ashtabula, located a few kilometers from the River mouth and the only major urban area on the Ashtabula River, has a heavy concentration of industrial development, particularly on the east side of the Harbor. Upstream from the town, much of the flood plain has a wooded cover.

21. Ashtabula Harbor serves as a major redistribution center for cargo being handled between ships and terrestrial forms of transport. Coal and iron ore, which respectively accounted for 42.6% (4,631,000 tons) and 48.3% (5,256,000 tons), were the most abundant materials that passed through the Port in 1973.

22. The industrialized areas around Ashtabula discharge quantities of contaminants to the Ashtabula River and Fields Brook, a minor tributary of the River near the Harbor. Pollution derived from the agricultural areas along the upper reaches of the River consists mainly of sediment and agricultural runoff. Fields Brook was described in a 1968 report by the Department of the Interior as having "ever present milky white or brown discoloration with strong chemical and medicinal odors". However, pollutant loadings to Lake Erie from the Ashtabula River have decreased significantly since the end of 1972 (Reitz 1973).

23. The Ashtabula area contains four types of waste treatment systems: septic tanks, privately owned domestic treatment facilities, industrial waste treatment facilities, and municipal waste treatment facilities.

24. The Cleveland Electric Illuminating Company has two fossil fuel-powered generating stations east of the Ashtabula Harbor, which have intakes in Lake Erie. Discharge of cooling water to the Lake occurs via a system of baffled ponds and five discharge lines. Two of these lines discharge 403 MGD and 172 MGD of cooling water, which is approximately 6° C to 9° C above the temperature of the intake water. Two of the three remaining lines operate in the ash pits and together discharge a total of only 5.8 MGD. The discharges have a settleable solids content of around 100 mg/ℓ, which will shortly be reduced to 30 mg/ℓ. The fifth discharge line carries miscellaneous plant water and discharges only 2.7 MGD (Anon 1975).

Physiography

25. The Ohio landscape along Lake Erie is part of the Erie-Ontario Lowlands Province. Largely shaped during the Cenozoic, the province includes the flat, low-lying areas which border the southern shores of Lake Erie and extends approximately 3.22 km to 80.45 km inland, where it is bordered on the south by the Appalachian Uplands Province. The lowlands rise gently to the east and south from an elevation of 570 m above mean sea level (msl) at Lake Erie to about 1000 to 1500 m above msl along the Portage Escarpment which marks the southern limits of the province. Within the province, east-west trending escarpments are formed by Onondaga limestone and by Lockport dolomites which form the cap rock of Niagara Falls. Glacial deposition has left drumlin fields, recessional moraines, and shoreline deposits which modify the simple erosional topography.

26. Ashtabula is located on the southern shore of Lake Erie in the northeastern corner of Ohio. At this point, the western portion of the Erie-Ontario Lowlands is only about 4.8 km wide. The Lake plain here is elevated 9.1 m to 12.2 m above the Lake. The plain is relatively flat, except where tributaries to Lake Erie have dissected the area (Anon 1974).

27. The Erie-Ontario lowlands were formed from Cenozoic materials and, in the vicinity of Ashtabula Harbor, are underlain by shales of the Ohio group. The rock surface of this group is relatively flat and dips gently towards the Lake. In the upper portions, the shale has weathered extensively and consists of shale fragments and clay. Below the weathered zone the shale is soft, highly fractured, and contains thin clay seams. Soil overlies the shale at the shoreline and in the bluff which is located immediately inland. At the shore, the overburden is approximately 0.6 m thick and consists of sand and gravel. The bluff is a glacial moraine composed of dense silt and clay silt soils capped by lacustrine clay and silty sands. Alluvial deposits from the Ashtabula River are also present and extend into Lake Erie, well past the Harbor breakwaters.

28. The Ashtabula Harbor is located in Ashtabula County, which is part of the Allegheny Plateau section on the northwestern edge of the Appalachian Plateau. A steep escarpment consisting of Mississippian and Pennsylvanian sediments is located about 3.2 km south of Ashtabula and characterizes the topography of the area (Danek et al. 1977).

29. The geological formations that comprise the Allegheny Plateau include Ohio shales formed during the Devonian period. Fragments of this fossil shale were found in most clay fractions of the sediments in the Ashtabula vicinity (Danek et al. 1977). This suggests that the Ohio shale was the parent rock for the soils and that shale had eroded through glacial abrasion. Large shale fragments also characterized areas of the proposed disposal site, located approximately 3.2 km north of the Harbor mouth. Surficial sediment materials in the general area consisted of alternating and mixed layers of mud, silt, sand, and hard sand with pebbles.

Soils

30. The Conneaut-Swanton-Claverack Association occupies areas that were covered with water following the retreat of the Wisconsin glacial ice from Ohio, and comprises a major part of those soils in the study area. The terrain on this old Lake plain is mostly level to gently sloping, but some steeper areas are located on breaks along streams. The major soils in this association were formed on silt loam material that was deposited in the old glacial Lake or in fine sandy deposits overlying silty material which is glacial till or Lake sediments. These soils have a root zone that is strongly acid to very strongly acid, or both.

31. Most of the soil in the Harbor region and in the industrial area to the east is classified as "Made Land" by the Soil Conservation Service. It consists of landfill, manganese ore tailings ponds, industrial waste lagoons, borrow pits, and those areas where the soil is covered by streets, homes, factories, or docks. In all of these areas, the original soils have been greatly altered.

32. Approximately 55% of the undisturbed soil in the area is

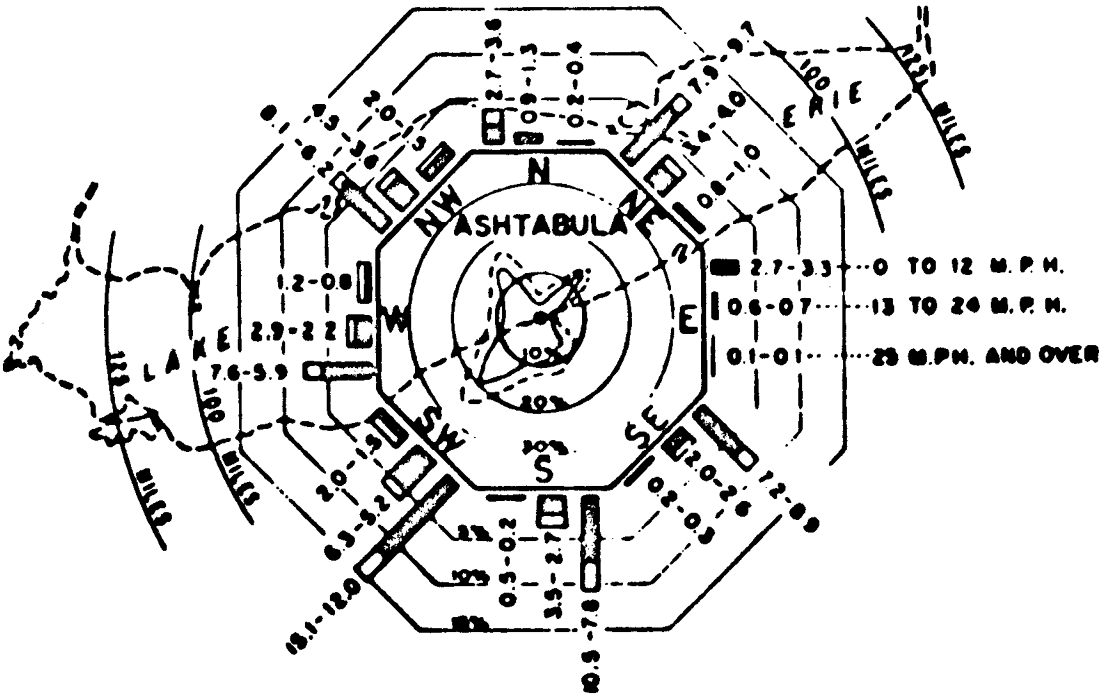
in the Conneaut Series, which are classified as poorly drained, loamy soils that generally occur on nearly level land. The upper part of these soils was formed in silt loam material that was deposited over glacial till. These soils are seasonally wet and require artificial drainage to improve crop yields. Many of the areas where they occur have been drained.

33. The erosion potential is high for soils in the Claverack, Plateau, and Braceville Series. These soils occur along the east bank of the Ashtabula River and the reaches of Fields Brook. The riverbed is composed of Lobdell silt loam. Because of the River's natural meander, erosion of the west bank has created an underlying layer of silt below the bedrock. The Lobdell material follows the old riverbed out into Lake Erie and under the west breakwater of the Harbor.

Climatology

34. The climate of the Ashtabula area is defined as "humid continental" and is characterized by large diurnal and annual fluctuations in temperature. Temperature extremes recorded at the nearest U. S. National Weather Service station approximately 16 km to the south-southwest at Geneva, Ohio, range from a summertime maximum of 36.7° C to a winter minimum of -27.2° C. Monthly average temperatures range from a low of -2.78° C during January to a high of 21.67° C during July. Some moderation of temperature extremes results from Ashtabula's close proximity to Lake Erie.

35. Annual precipitation in the vicinity of the project area averages 99.09 cm, with April being the wettest month (9.93 cm) and February the driest (5.89 cm). Precipitation distribution is rather uniform throughout the year. Measurable precipitation occurrences average 231 days per annum. Ashtabula's annual snowfall average of 183.64 cm is enhanced by west, northwest, or north winds creating lake-effect snows. Wind velocity is generally moderate with northwesterly and southwesterly prevailing winds. The frequency of occurrence of wind speeds and directions experienced at Ashtabula is shown in Figure 3. The strongest winds



NOTES

▬ INDICATES DURATION FOR ICE-FREE PERIOD (MAR. TO DEC. INCL.) IN PERCENT OF TOTAL DURATION.

▭ INDICATES DURATION FOR ICE PERIOD (JAN. TO FEB. INCL.) IN PERCENT OF TOTAL DURATION.

⌣ INDICATES PERCENT OF TOTAL WIND MOVEMENT OCCURRING DURING ICE-FREE PERIOD.

⋯ INDICATES PERCENT OF TOTAL WIND MOVEMENT OCCURRING DURING COMBINED ICE AND ICE-FREE PERIODS.

FIGURES AT ENDS OF BARS INDICATE PERCENT OF TOTAL WIND DURATION FOR ICE-FREE PERIOD AND COMBINED ICE-FREE AND ICE PERIODS, RESPECTIVELY.

WIND DATA BASED ON RECORDS OF THE U S. COAST GUARD LIFE BOAT STATION AT ASHTABULA, OHIO FOR PERIOD 1 JAN. 1937 TO 31 DEC. 1968 INCL., LESS 1944, AND 1960.

Figure 3. Wind rose for Ashtabula.
IN: Final Environmental Impact Statement - Operation and Maintenance, Ashtabula Harbor. U.S. Army Corps of Engineers, Buffalo District, Buffalo, NY. July 1975.

occur during the spring and summer, and are associated with thunderstorms moving through the area (Anon 1976a).

PART III: METHODS AND MATERIALS

36. Detailed descriptions of the methods and materials utilized in this study are provided in the separately published appendices to this report (see list of appendices on inside of front cover). Thus, the following information is essentially a summary. A chronology of sampling activities is shown in Table 3.

Physical Studies

37. The majority of the physical components of the Ashtabula Project were the responsibility of the Environmental Sciences Division of Industrial BIO-TEST Laboratories, Inc. (presently known as NALCO Environmental Sciences), Northbrook, Illinois. Measurements and collections in the field were closely coordinated with the biological and chemical components of the study.

38. The field methods used to achieve the objectives of the physical studies at the study site were: (a) bathymetry and subbottom profiling, (b) current measurements, (c) temperature measurements, (d) transmissivity, (e) wave measurements, (f) meteorological observations, and (g) sedimentology determinations. Information regarding Lake levels as measured hourly at a gauge at Fairport Harbor, Ohio (approximately 3.2 km west-southwest of Ashtabula), was obtained from the National Oceanic and Atmospheric Administration (NOAA) Lake Survey Center in Rockville, Maryland. Ashtabula River discharges were obtained from the United States Geological Survey (USGS) office in New Philadelphia, Ohio.

Positioning

39. Determination of sampling vessels and marker buoy locations for the physical as well as biological and chemical phases of the project was done by means of a Motorola Mini-Ranger Navigation System that had an accuracy of ±10 m.

Bathymetry and Subbottom Profiling

40. Bathymetric and subbottom profile surveys were conducted

TABLE 3

Sampling Chronology

Sampling Date	Sampling Event	PHYSICAL Bathymetry	Currents	Transmissivity	Temperature	Sedimentology	BIOLOGICAL Pelagic	Benthic	CHEMICAL Water	Sediment
11-13 June 1975	Initial Survey 1975	-	-	-	-	-	x	x	x	x
24 June 1975	40-day predisposal 1975	x	-	-	-	-	-	x	-	x
8-11 July 1975	27-day predisposal 1975	x	x	x	x	-	x	-	x	x
30 July - 2 Aug 1975	5-day predisposal 1975	x	x	x	x	x	x	x	x	x
4-14 August 1975	Disposal 1975	x	x	x	x	x	x	-	x	-
14-15 August 1975	Immediate postdisposal 1975	x	x	x	x	x	x	-	x	-
19-20 August 1975	5-day postdisposal 1975	-	-	-	-	-	x	x	x	x
11-14 September 1975	28-day postdisposal 1975	x	x	x	x	x	x	x	x	x
19 October 1975	66-day postdisposal 1975	-	x	x	x	x	x	-	x	x
12 November 1975	90-day postdisposal 1975	x	-	-	-	-	-	-	-	-
16-17 November 1975	94-day postdisposal 1975	x	x	x	x	-	x	x	x	x
20 December 1975	128-day postdisposal 1975	-	-	-	x	-	-	-	-	-
26-28 March 1976	225-day postdisposal 1975	x	x	x	x	-	-	-	-	-
20-21 April 1976	250-day postdisposal 1975	x	x	x	x	-	x	x	-	-
	30-day predisposal 1976	x	x	x	x	-	x	-	x	-
13-16 May 1976	271-day postdisposal 1975	x	x	x	x	x	x	-	x	-
	9-day predisposal 1976	x	x	x	x	x	x	x	x	x
24-26 May 1976	Disposal 1976	x	x	x	x	x	-	x	-	-
7-11 June 1976	298-day postdisposal 1975	x	x	x	x	x	x	-	-	-
	5-day postdisposal 1976	x	x	x	x	x	x	x	x	x
7-9 July 1976	328-day postdisposal 1975	x	x	x	x	x	x	x	x	x
	35-day postdisposal 1976	x	x	x	x	x	x	x	x	x
27 July 1976	55-day postdisposal 1976	-	-	-	-	-	x	-	-	-
8-14 September 1976	98-day postdisposal 1976	x	x	x	x	x	x	-	-	-

NOTE: Fisheries were sampled on a monthly basis from July through November 1975 and March through September 1976 with intensive net and fathometric surveys during each disposal period.

using a portable Raytheon DE-719B continuous recording fathometer (200 khz) and a Raytheon RTT-1000A Portable Survey System (7 khz). These systems had accuracies of ±0.5%. Corrections for changes in Lake level elevation were made based on hourly Lake level data from the Fairport, Ohio, gauge.

41. During the periods 23-27 June and 7-11 July 1975, large-scale and detailed bathymetric and subbottom surveys were conducted to establish baseline reference for the study area. The large-scale survey taken before the disposal operation consisted of 22 north-south transects at approximately 300-m intervals covering the entire 35-sq-km study area. The same measurements were taken again in September 1976 so that changes in the bathymetry could be determined.

42. Four control transects were established to monitor large-scale seasonal changes that might occur within the study area. The transects were approximately 7 km long and oriented north-south. These transects were surveyed monthly and the results were plotted and examined to detect any changes in bottom contours. These transects were also used to estimate the precision of the fathometer and the accuracy of the positioning techniques.

43. Detailed surveys in the vicinity of Disposal Sites D2, D8, and NDS (Figure 1) were conducted before and after disposal operations. These surveys were used to examine the size of the sediment pile and monitor changes within and resulting from the disposed sediment. Radial survey patterns centered on the Disposal Area as well as rectangular grid patterns were used to survey the Disposal Sites. The combined data from the two types of surveys were used to develop the bathymetry plots.

Current Measurements

44. Time continuous current measurements were made at a permanent mooring installed in 17 m of water at location PC1 (Figure 1) on 8 July 1975. ENDECO Type 105 current meters and Type 109 thermographs were secured to the mooring at 1 and 3 m

above the bottom (Figure 4). Current speed and direction were recorded as 30-min averages continuously from June 1975 to September 1976. The instruments were serviced monthly, which included replacing of batteries, film, and desiccant bags and checking the instrument trim.

45. The current meters were axial flow, ducted impeller instruments specifically designed for use in the nearshore zone. Analog values of impeller rotation and magnetic bearing of the instrument comprise the data that were recorded on 16 mm film. Each instrument was calibrated prior to installation in a closely controlled flume to determine threshold speed and accuracy of measurement. The most recent calibrations were conducted by personnel at the Environmental Devices Corporation (ENDECO). Threshold speeds were determined for each current meter and were found to be between 2 and 3 cm/sec. Accuracy of speed measurement was determined to be within ± 0.6 cm/sec of the true speed. Current direction accuracy was ± 5° at threshold speed, ± 3.6° above threshold speed, and is resolvable to ± 1.0°.

46. Time series data of 30-min averages of current speed and direction were analyzed in several ways. The data were used to construct plots of speed and direction versus time, progressive vector diagrams (PROVECS), joint frequency tables of current speed and direction, persistence tables of current speed, power spectra estimates, and current roses. A detailed discussion of how the PROVECS were determined is provided in Appendix C.

47. Over-the-side vertical profiles of the currents were taken each month at locations PC1 and TC1-TC6 (Figure 5) with an electromagnetic current meter (Marsh-McBirney Model 727). Currents were normally measured at 1 and 3 m above bottom, middepth, and 1 m below the surface. The output signals of the electromagnetic current meter were recorded by a Rikadenki three-pen analog recorder (Model B38). The instruments were linked to a Nova Inverter to eliminate electronic interference from the boat's generator. The analog recording of the X and Y velocities and the orientation of the current meter case were digitized in the laboratory for analyses.

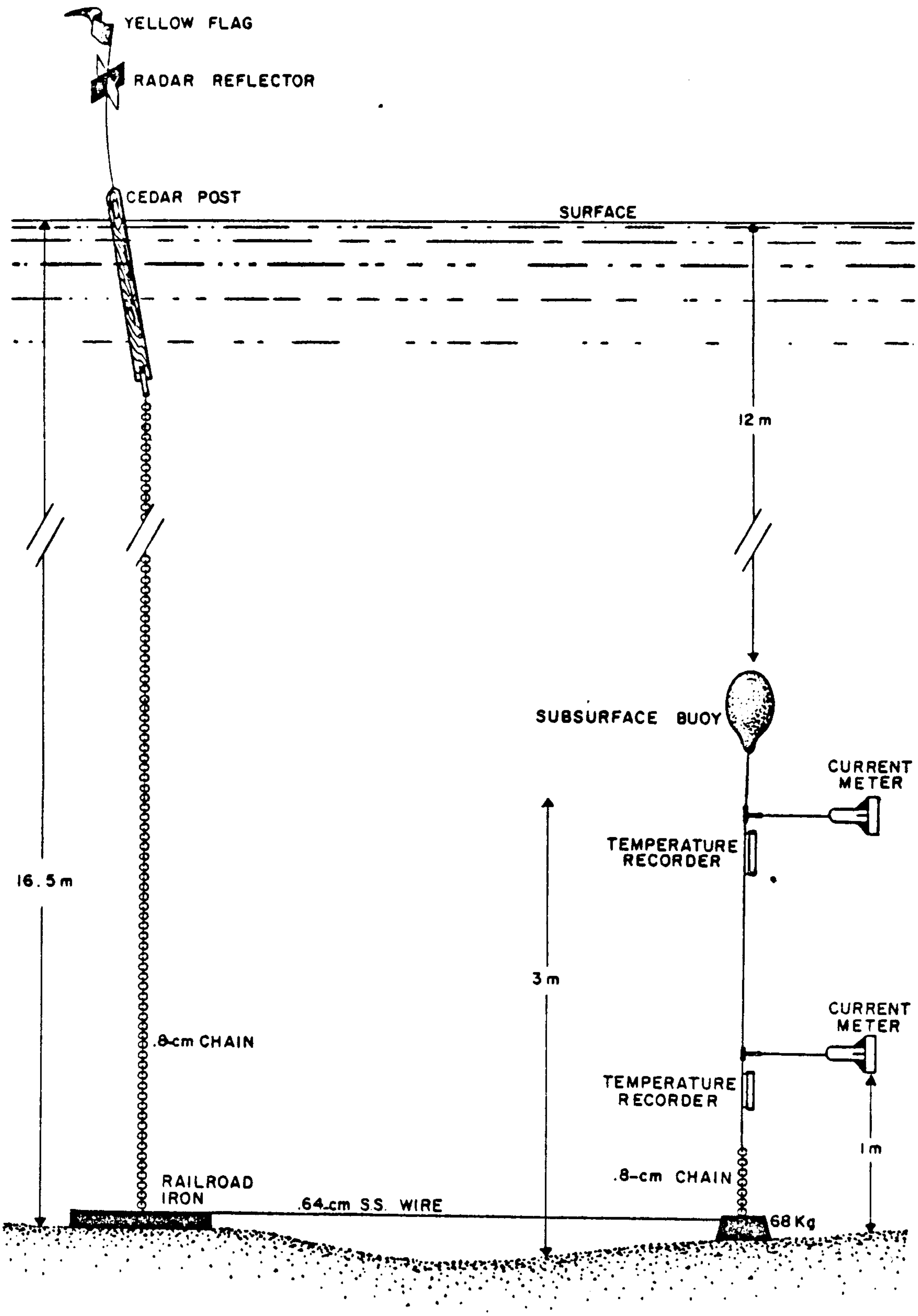


Figure 4. Current meter and thermograph mooring

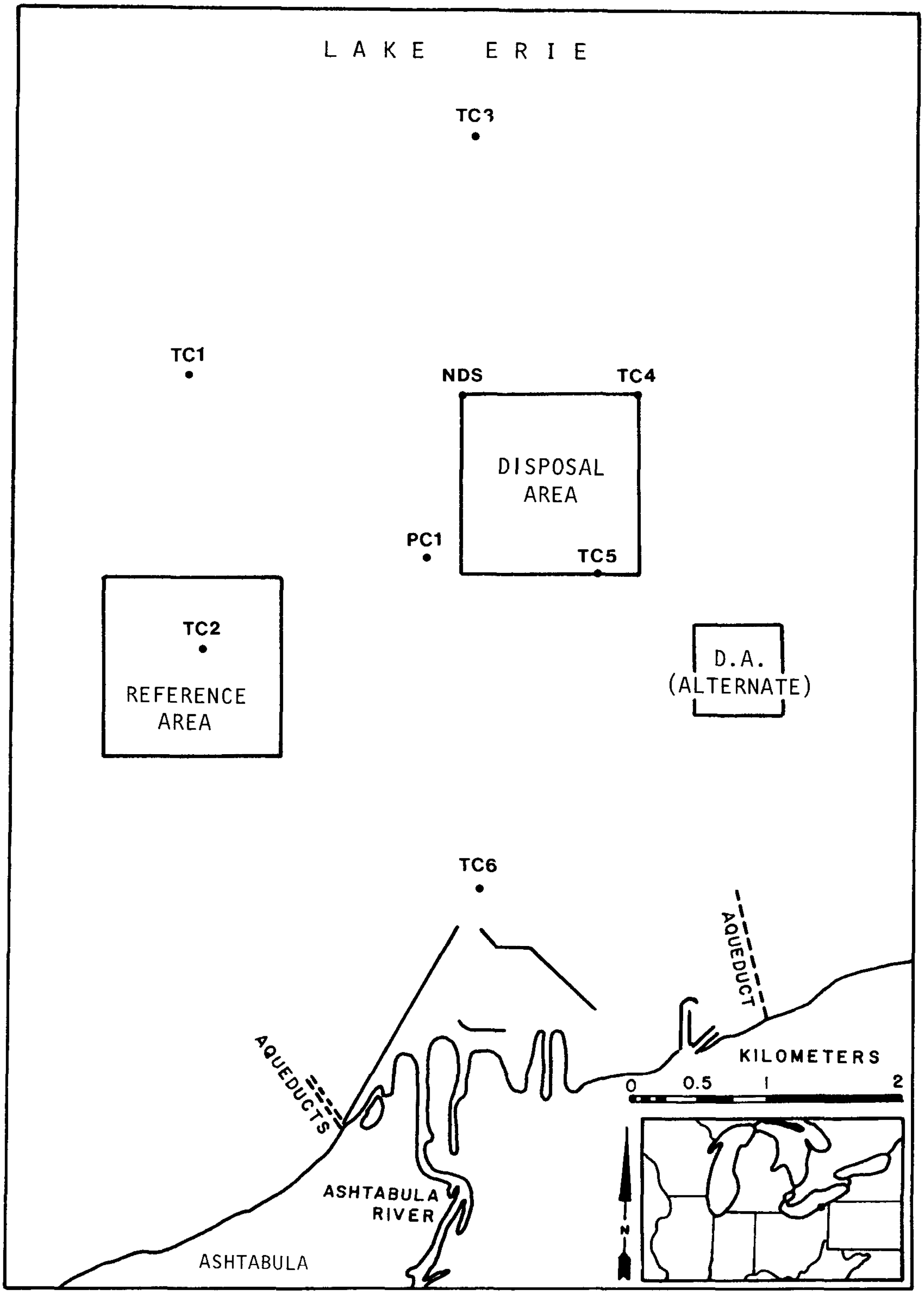


Figure 5. Location of permanent mooring for continuous current and temperature measurements (PC1) and locations for vertical profile measurements of temperature, transmissivity and current (TC1 through TC6) relative to the location of the northwest disposal site (NDS)

48. The current meter has a stated threshold velocity of 0.6 cm/sec, which is also the resolution of the recorded velocity components. Absolute accuracy of the measurements is specified as being ± 2% of the instrument readout. Maximum long-term drift, which is an inherent instrument error, is approximately 1.9 cm/sec. Consequently, under worst-case conditions of large zero-drift, the measurements could be in error by as much as 2 cm/sec. Additional error can be induced into the measurements if there is substantial vertical movement of the instrument such as induced by wave action on the boat.

49. The current-meter probe was held at each depth for 3 min, and the continuous measurements for each depth were averaged to determine the current velocity. The results were plotted so that vertical shears in the horizontal velocity could be readily observed. These measurements were used during the disposal operations to quickly assess the relative direction of current movement with depth in order to position anchored survey vessels. The measurements were also intended to provide information on the horizontal and vertical variability of the currents.

Temperature Measurements

50. Continuous temperature measurements were made concurrently with the permanent current meter measurements. Two ENDECO type 109 recording thermographs were attached to the mooring, one directly beneath each current meter. The two thermographs recorded half-hourly averaged temperature on 16 mm film with a resolution of 0.1° C and an accuracy of ± 0.2° C. The time constant of the instrument was 10 min. The thermographs were serviced simultaneously with the current meters with the replenishment of new batteries, film, and desiccant bags.

51. Half-hourly averages of temperature versus time were plotted for each month and each station. The maximum, minimum, and mean temperatures were determined for each month and compared by station and month. Episodes of large temperature fluctuations were noted, and the wind record and current meter records were examined to locate possible causes for the variations.

52. Measurements of ambient temperature profiles at Stations TC1-TC6, PC1, and NDS (Figure 5) were made monthly between July 1975 and September 1976 (with the exception of December 1975, and January, February, and August 1976), as well as during disposal operations, using a precision thermistor temperature probe (M & F Engineering). This instrument provided a resolution of 0.01° C and an accuracy of 0.05° C. Temperature measurements were made at 1- to 2-m depth intervals. Vertical temperature profiles were plotted for each transect with a computer plotting package and noticeable changes in the thermocline were examined.

Transmissivity Measurements

53. Transmissivity measurements were taken monthly and during disposal operations with a Montedoro-Whitney TMA-1A Transmissometer. This instrument measured the percent of light that was transmitted across the 1-m span between the light source and the sensor. The instrument was designed to work accurately in water up to 100 m deep. The relative accuracy was 2% with a resolution of 1% of the range. The instrument was balanced at every station before obtaining measurements by setting the absorbed light level to 100% with the probe in the air and the mirror and light windows wiped clean. The source was then covered with a piece of cardboard and the readout adjusted to 0%. Readings were then obtained at 1- or 2-m increments to the bottom. The data were plotted by computer on the same graphs as the temperature data. The data obtained during disposal activity in 1975 were computer plotted in three dimensions representing the time variations of transmissivity within the water column.

54. During the dredging operation in 1975, five transmissometers were used to measure changes in the transmissivity resulting from the disposal activity. An attempt was made to intercalibrate the transmissometers but the readings varied considerably, and it was impossible to convert the values from each transmissometer to a standard scale. Consequently, the values presented only show relative changes in the transmissivity and the measurements given

are the percent of light transmittance in the water relative to 100% in air. An attempt was also made to compare total suspended sediment measurements with the transmissivity but the data were so variable that no useful correlation could be made.

Wave Measurements

55. Wave measurements were made with a Bass Engineering Model WG/100M self-contained wave measuring and recording system that was installed in approximately 17 m of water near Station PC1. The instrument sensed pressure fluctuations with a Bourdon tube pressure transducer whose signal was transformed with an optical lever system to produce a variable voltage output. The operation of the optical lever system is described in detail by Bass and Byrnes (1974). This system determined water surface variations with a precision of ± 0.02 m and a resolution of ± 0.01 m. The timing was controlled by a crystal clock that had an accuracy of ± 0.01%. The wave field was sampled every 4 hr for a 10-min interval during which time measurements were taken every 0.5 sec. In March 1976 the sampling rate was changed to 1.0 sec to increase the recording capacity of the instrument. The data were recorded on a magnetic cassette that was later decoded. The results were then stored on magnetic tape.

56. The data were edited to remove all non-numeric digits from the data and also to check for the proper timing sequence that precedes each data set. The resulting data sets were then detrended and the mean was subtracted, which left only the pressure fluctuations about a zero mean. The residual pressure readings were subsequently plotted and examined visually to remove any outlying points. All erroneous points were replaced by a linear interpolation of the two adjacent points. The clean data sets obtained after the editing process were used for subsequent analyses. A discussion of the zero-up-cross method that was used to analyze the wave data appears in Appendix C.

Meteorological Measurements

57. A 10-m crank-up tower was erected approximately 1 km

south and inland from the harbor. A Meteorology Research Incorporated Model 1071 Mechanical Weather Station was secured to the top of the tower and analog values of wind run, wind direction, and air temperature were continuously recorded. The threshold of the instrument was 0.34 m/sec for both the vane and the cup anemometer. The speed was recorded with an accuracy of ± 2% of the measured value and the direction with an accuracy of ± 3.6° and a resolution of 15°. The weather station was serviced monthly, which included the replacement of batteries and strip-chart paper.

58. The data were read from the analog records and digitized as hourly averages. The results were then used to construct plots of speed and direction versus time and also to make PROVECS, joint frequency tables of wind speed and direction, and persistence tables of wind speed. Hourly temperature data, which were recorded with an accuracy of ± 1° C, were also tabulated. An Eppley Black and White Pyranometer Model 8-48 was installed approximately 3 m aboveground on the south side of a tower at Sutherland Marina, Ashtabula. The instrument recorded the solar radiation in langleys per minute with an accuracy of ± 2% of the measured value. An analog recorder for the solar-radiation data was placed inside a trailer next to the tower. No shadows from obstructions were cast on the pyranometer at anytime during the day. It was cleaned and serviced monthly.

Hydrological Measurements

59. Hourly lake level data collected at Fairport Harbor, Ohio (32.18 km west of Ashtabula) were obtained from the Lake Survey Center in Rockville, Maryland. Ashtabula River discharge data were obtained from the United States Geological Survey (USGS) in New Philadelphia, Ohio. Daily values of water level and river discharge were tabulated as well as hourly water-level values during periods when the bathymetric surveys were being conducted.

Sedimentology Determinations

60. Traps for collecting suspended sediments were designed and implemented as a means for studying sediment distribution and movement. The purpose of the sediment traps was to collect suspended

sediments that were disposed by a dredging vessel or resuspended by current and wave activity. By using a number of sediment traps in a grid system, sediment distribution and movement patterns were determined by analysis of the trap contents.

61. The collection tubes in the sediment traps were plastic core liners 30 and 50 cm long that were closed on the bottom with a plastic cap. The longer traps were used near the center of the Disposal Area where deposition would be the greatest. Traps and holders were installed and retrieved by a diver; the traps were covered prior to retrieval with a plastic cap having a pressure-release hole. No disturbance of the samples was observed during the trap removals. A detailed description of the traps is given in Appendix C. Of the eight sediment traps at each site, two were collected for analysis during each field study and the others were left undisturbed. This provided information on the compaction rate of the sediments and the characteristics of their vertical distribution. The samples collected from the traps, as well as grab samples and cores, were analyzed for grain-size distribution by the Great Lakes Laboratory. The compaction rate of the sediments was estimated by comparing the height of the sediment in the traps from the final collection with the height of the sediment from the previous postdisposal samples. This, of course, assumed that only negligible sedimentation occurred in the months following the disposal operation, which was verified with the data from Reference Site C3.

62. In order to collect additional data on the quantities of deposited and redistributed sediments, survey rods were installed next to the sediment traps. The rods also are described in Appendix C.

63. The shear strength of the sediments was measured in situ with a specially designed instrument. The instrument was made from a torque screwdriver with an attached, calibrated scale for reading the torque values. Two different instruments were made, one with a 0 to 6 oz-in. scale for the very loose sediment

and the other with a 0 to 48 oz-in. scale for the sediments with greater shear strengths.

64. To obtain the measurements, the diver carefully pushed the vane into the sediment to a predetermined depth and then rotated the handle slowly until the sediment began to shear. The torque required to produce the shear was read directly from the instrument and recorded. The torque values were then converted to pounds per square inch.

65. Shear strength measurements were taken at 5-cm intervals down to a depth of 30 cm at each station. The measurements were taken at the same stations where the sediment traps and survey rods were located. The results were tabulated as well as plotted and contoured on a base chart. Vertical profiles of the sediment shear strength were also plotted for both north-south and east-west transects.

66. Over 200 sediment cores were taken by Great Lakes Laboratory staff with a K-B Gravity Corer. Samples were collected from sites within the Disposal Area and the Reference Area during monthly sampling periods in 1975 and 1976. Four replicates were collected for all the 1975 samples and two replicates were taken for the 1976 samples. Three different sections from each core, at approximately 7-cm intervals, were analyzed for particle-size distribution by means of the F.A.S.T. technique. These data were recorded in weight percent and then plotted as weight percent vs. grain size (in phi units). The data plotted were the mean average of the replicates. The purpose of these plots was to provide a quick check on the distribution of the sediments.

67. Eleven additional sediment cores were collected by a diver in the Northwest Disposal Site (NDS) during 1976. The core samples were X-rayed at the Department of Geological Sciences, University of Toledo, Toledo, Ohio. Radiographs as well as X-ray transmission plots for two energy levels were made of each sample to show structures of the sediments, density differences, coarse particles, bioturbations, and porosity discontinuities within the

cores.

Statistical Procedures for Analyzing Physical Data

68. The procedures, which included use of linear discriminate and multivariate analysis of variance programs from Statistical Packages for the Social Sciences (SPSS) version 6.51 (Nie et al. 1975) and MANOVA (Cohen and Burns 1973), are described in Appendix C.

Biological Studies

69. The biological phases of the Ashtabula Project were the responsibility of the Great Lakes Laboratory (GLL) of the State University College at Buffalo. Components included: (a) phytoplankton enumerations, (b) pigment analyses, (c) measurements of primary productivity, (d) elutriate-primary productivity bioassays, (e) pelagic zooplankton enumerations, (f) benthic macroinvertebrate enumerations, and (g) fisheries investigations. The fisheries components were carried out by the Cleveland Environmental Research Group of Cleveland, Ohio, under the supervision of Dr. Andrew White.

Phytoplankton Enumeration

70. At each pelagic station, PW1 through PW11 (Figure 2), the percent transmittance of surface light was measured at 1-m depth intervals through the water column with a submarine photometer (Kahlsico #286WA310). From this procedure the depths for 25 and 1% transmittance were determined. A water sample was collected at 1 m below the surface and at each of the above transmittance depths using an 8 ℓ Van Dorn water sampler. The water from all three depths was subsampled (75 mℓ each) to give a composite sample representing the entire water column (as deep as 1% light transmittance). This composite sample was collected in triplicate (three separate Van Dorn sampler drops) at each of the pelagic sites during 1975, while duplicate samples were collected during 1976. The plankton in each sample were preserved with modified Lugol's solution and identified and enumerated using inverted

microscopes according to the methods of Utermohl.

Pigment Analyses

71. The water samples taken at each pelagic station for phytoplankton, including 1 m below the surface and at 25 and 1% light transmittance, were also subsampled for measurement of phytoplankton pigments. As for phytoplankton, triplicate subsamples were taken at each depth. These were filtered through Whatman GF/C glass-fiber filters (0.45 μ) to which five drops of magnesium carbonate were added. The filters were kept frozen in the dark until laboratory analysis.

72. Filters were homogenized in 90% basic acetone and centrifuged for 10 min after a minimum of 2 hrs extraction in the dark. After centrifugation, the pigments were spectrophotometrically determined (Beckman DB-GT Spectrophotometer) by the methods of Strickland and Parsons, and phaeopigments were determined by the method of Lorenzen. The results of the pigment analyses were expressed as milligrams chlorophyll a per cubic meter of the water column.

Measurements of Primary Productivity

73. Primary productivity estimates were obtained for the same pelagic stations for which phytoplankton enumeration and pigment analyses were performed. Water samples were collected with a Van Dorn water sampler at 1 m below the surface and at the depth of 25% light transmittance. During this study the latter occurred at 2.3 or 5 m. Collections were placed in triplicate 125-ml ground-glass-stoppered Pyrex bottles (two clear and one opaque). Two of these triplicate sets (three separate Van Dorns) were taken at each depth. Rates of primary productivity were measured by the ^{14}C technique.

Elutriate-Primary Productivity Bioassay Determinations

74. Sediment samples from the mouth of the Ashtabula River were obtained on 15 May, 11 June, 17 July, and 14 September in 1976 using Ponar grabs while water samples were taken with a Van Dorn water sampler. The dredged material elutriate water was prepared from these as described in Appendix C. In addition, for each experiment, 5 ℓ of Lake water were filtered through

0.45 μ membrane filters to remove all phytoplankton. On each occasion that the elutriate-primary productivity bioassays were conducted, a large volume of Lake water was taken within the Reference Area at 1-m depth and mixed into a composite sample. From this composite, sets (two clear and one opaque) of 125 mℓ ground-glass-stoppered Pyrex bottles were filled. These incubation bottles were divided into treatment groups, each group containing three sets of bottles. The bottles each had 25 mℓ of water removed with a continous syringe.

75. Treatment levels were established using the dredged material elutriate, the sets of Lake water samples from 1 m, and the filtered Lake water. The following treatment levels were used in the bioassays:

Number of Light Bottles	Number of Dark Bottles	Elutriate Added mℓ	Filtered Lake Water Added mℓ
6	3	0	25.0
6	3	0.1	24.9
6	3	1.0	24.0
6	3	5.0	20.0
6	3	10.0	15.0
6	3	15.0	10.0
6	3	25.0	0.0

76. After addition of the filtered Lake water and elutriate to each group of treatment bottles, the bottles were inoculated with 1.0 mℓ of $NaH^{14}CO_3$, randomly placed in the bottle holders, and incubated in the Lake at 1 m for a 4-hr incubation period. After incubation the photosynthesis was stopped with 1.0 mℓ of neutral formalin, and the samples were filtered through membrane filters (0.45 μ). The filters were placed in scintillation vials containing Insta-Gel and counted in the laboratory according to the procedure described above for primary productivity measures.

77. Activity of the phytoplankton cells, as measured by the scintillation counting, was used to measure the photosynthetic response of the organisms. Total counts of the Reference samples

(no addition of dredged material elutriates) were considered as normal photosynthesis. Radioactive counts for the various dilutions of elutriate were compared to the References. The dark bottle elutriate results were found to be especially valuable because they also accounted for any heterotrophic activity that may have influenced the final result. Thus, the heterotrophic activity could be measured and subtracted to ascertain the impact on phytoplankton activity.

Pelagic Zooplankton Enumeration

78. Samples were taken at each of the pelagic water stations (PW1-11 on Figure 2) through triplicate hauls of unmetered plankton nets with a mouth diameter of 40 cm and a mesh size of 64 μ. Vertical hauls were made from 1 m above the bottom to the surface at each station. The collections were concentrated in a Wisconsin plankton bucket by washing, the buckets washed into jars, and the samples preserved in 10% buffered formalin and 5% glycerin.

79. In the laboratory taxonomic identifications to the species level, if possible, and estimations of abundance of crustacean zooplankton were performed using a compound microscope (Bausch and Lomb Stereo Zoom 7). A minimum of 200 animals, excluding copepod nauplii, were counted for each sample. Numbers per cubic meter of the water column were calculated from the volume of the subsample counted, assuming a plankton net efficiency of 100% (collection of all organisms in the water column), depth of tow, and net diameter. The values from the triplicates were averaged to obtain the results per station.

Benthic Invertebrate Analyses

80. At each benthic station or within each quadrat (depending on year of sampling) samples were obtained from the bottom sediments using a General Oceanographics box corer with a surface sampling area of 151.56 cm^2. During the 1975 cruises four replicate benthic samples per box corer sample were taken at each station shown in Figure 1. In 1976 the benthic sampling was reduced to two replicates per collection. The 1975 stations were sampled along with Quadrats SD1 through SD16 (Figure 6). The samples were removed

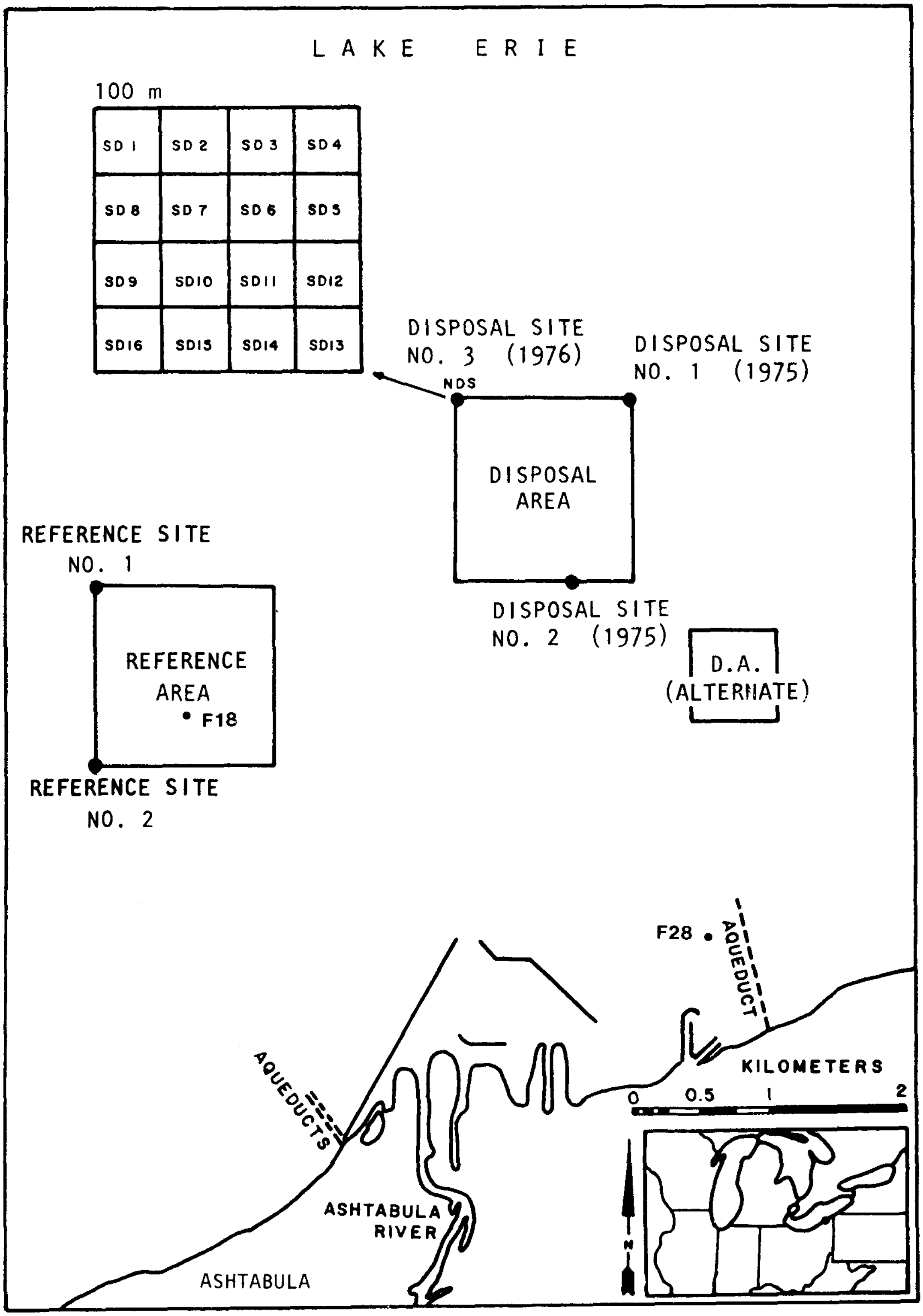


Figure 6. Station locations for reference sites and disposal sites (SD1-SD16) for deposition of material dredged from Ashtabula River in 1976

from the box corer and separately sieved through #30 mesh USGS sieves. The organisms and any remaining material were washed from the screen into jars and preserved in 10% neutral formalin and 5% glycerin. In cases where the cores were to be examined for vertical distribution of organisms the core was extruded into a wooden frame and sectioned with horizontal slats at the vertical intervals of 0-5, 5-10, 10-20, and > 20 cm . During 1976, the intervals were 0-5, 5-10, and > 10 cm. Each section was then sieved separately and preserved according to the above.

81. For benthic meioinvertebrate fauna (fauna passing through the #30 mesh screen and retained on the #60 mesh screen), a subsample was removed from the box corer sample using a 4.8-cm-diam. plexiglass tube. As with the macroinvertebrate enumeration, four replicate samples were taken for meioinvertebrate examination in 1975 and two replicates were taken in 1976. The total samples were extruded into jars and preserved in 10% formalin and 5% glycerin for sieving later in the laboratory. Samples that required sectioning were partitioned on the boat as above and then preserved in sample jars.

82. In the laboratory the sieved samples were stained with Rose Bengal, sorted, picked using a Stereozoom binocular microscope (Bausch and Lomb Model BV8-73), and preserved in 70% ethanol according to the methods of the EPA (1973). The meioinvertebrate samples were sieved in the lab through standard #30 and #60 mesh sieves. The fauna retained by the #60 mesh were treated in the same manner as the macroinvertebrate fauna for sorting.

Fisheries Investigations

83. The primary sampling technique used was the gill net. Because of catch selectivity, two types of gill nets were used: monofilament and braided nylon. The monofilament net, 500 ft. in length, 6 ft. deep, contained a series of 50-ft. panels of varying mesh sizes. These were of 1/2-in. intervals from 1-1/2 to 6 in. stretch mesh. The nylon net was 100 ft. in length and consisted of four 25-ft. panels (1-1/2, 2, 3, 4 in. stretch mesh). These nets were attached to each other making a complete net of 600 ft.

84. Nets were set at the bottom of the Lake and remained at

a station for no less than 18 hrs and normally for no longer than 24 hrs. Occasionally weather conditions prohibited retrieval. These collections were considered invalid since catch per unit of effort normally decreases over extended periods of time. This is due to the increased amount of debris and dead fish in the net.

85. When nets were retrieved the fish were immediately removed and either frozen on dry ice or placed on ice. Species which decomposed easily, such as alewife, were injected with formalin to preserve the gut contents. Specimens were returned to the laboratory where they were either processed immediately or frozen for future processing. The otter trawls, seines and larval tow nets as well as the fathometric tracings that also were employed throughout the study are described in Appendix A.

86. Adult fish collected were processed in the laboratory either fresh or after thawing. Weight and length (standard and total) were recorded for each specimen. Scales were removed from the left side of each fish at a point above the lateral line and just below the dorsal fin insertion. Scales were placed in serially numbered envelopes. The specimen was then opened and the sex was determined. Sex, length, weight, date of collection and collection site were recorded on data sheets and on the scale envelopes. The stomach was then removed and placed in a vial of 5% formalin. The vial was numbered with the same number assigned to the scale sampled. The mouth and esophagus were examined and any food material present was added to the stomach vial. Stomachs which were ruptured were recorded as such on the laboratory data sheets.

87. Fish scales were impressed on plastic (1 x 3 in.,.040 in.) slides using an Ann Arbor Scale Roller Press. Impressions were read to determine ages according to techniques described in standard literature sources. Ages were determined by two different readers and the results compared.

88. Those readings which were in conflict (less than 5%) were reread by a third individual. All age determinations were corrected to reflect months of age rather than the normal technique

of years plus. This was done by comparing known spawning month, date of collection, and number of annuli present. Ictalurids were not aged because of the time and difficulty involved in sectioning pectoral spines. Spines were collected, however, and have been stored for future reference.

89. The contents of each stomach were removed and examined under a binocular dissecting microscope. Organisms present were removed and placed in clean solutions of 5% formalin. Detritus present was then examined under a compound microscope for the presence of algae, oligochaete setae, etc. All organisms present were enumerated and identified to the lowest taxon possible.

90. The procedures that were followed in the identification of stomach contents, including algae, zooplankton, benthos, and detrital materials, are described in Appendix A.

91. On 28 May 1976 an in situ experiment to evaluate egg survival, using rainbow trout eyed-eggs obtained from a commercial supplier, was initiated. Fish egg containers used in the bioassay tests were constructed of plexiglass. Frames were made and covered with 18 mesh per inch nitex netting. Three boxes were placed on each plexiglass base to serve as replicates. The base was attached to an anchor and buoy. The eggs were acclimated to the Lake surface water at the Disposal Site by successive water changes over a period of 2 hrs. After acclimation was completed, each container received 50 eggs and was placed in the Lake. Racks of three boxes each were lowered at a rate of 1 m per 5 mins. to minimize the effect of temperature and pressure changes. Racks were placed as controls at Station F18, and to determine the effect of depth a rack was placed at Station F28 (Figure 6). Racks also were placed at 100, 150, 200, and 250 m on a southerly line from the center of NDS. Egg boxes remained at each site during the remainder of the disposal period.

92. Egg racks were lifted and checked for silt content, development of eggs and hatching success. The racks were lifted

at a rate of 1 m per min to maximize pressure acclimation of developing individuals. Successive lifts of racks at Stations F18 and F28 indicated a minimal effect on mortality due to pressure or temperature change.

Statistical Procedures for Analyzing Biological Data

93. A principal components analysis (community ordination) was performed on the phytoplankton and zooplankton analyses to aid in the interpretation of the differences between the Reference and Dredged Material Disposal Sites. Although the major impact from disposal was expected on the benthic environment, it was believed that effects might occur in the biota of the overlying water from recycling and resuspension processes. The principal components analysis presented a useful means of examining the data from the taxonomic analyses. It represented the communities with similar records by close positioning of points on a two-dimensional plot. Communities with dissimilar characteristics were plotted at a distance from one another. The function of the principal components process was to reduce the intangible sample n-space to a space whose dimensions were much less than n and yet preserve as much similarity/dissimilarity information as possible. The assumption was that the position of points or cluster of points along a graphical axis may reflect community relationships. The similarity index used was Euclidian distance. The above method also was used on the benthic invertebrate faunal list for each station for each sampling date to identify varying differences over time between the Disposal and Reference Sites. The method of community ordination used here was based on the principal component analysis. The analyses were performed using a modified version of a FORTRAN program.

94. A discriminant analysis routine was also used on the total numbers of major benthic taxonomic groups observed at each site in order to distinguish statistical differences between the

sites chosen a priori as defined by their various communities. The objective of using this statistical analysis procedure serves as an index for discriminating between groups. In this manner, Reference and Center Disposal Sites data could be discriminated by new varieties that would differentiate them as statistically distinct from one another as possible. After these groups were analyzed and their discriminant functions defined, the remaining Experimental Sites were classified into one of the two groups based on community similarities. This information provided an evaluation of the actual size of the area impacted by disposal and the recovery of sites with time which were not as impacted as the center areas. Stepwise calculations were made in order to identify the variables most significant in contributing discriminatory power to any sites that showed differences from others. All computations were made to a significance level of $P \leqslant 0.05$. The analyses were done on the IBM 360 computer using the Statistical Package for Social Sciences (SPSS) Discriminant Analyses (Nie et al. 1970).

95. A one-way analysis of variance was used to test for significant differences among treatment levels of the elutriate primary productivity experiment. The analysis of variance summary table provided the F-ratio and test of significance for variance between the several groups (concentrations of elutriate addition). The results were considered significant at $P \leqslant 0.05$. A priori contrasts were also specified for each of the elutriate addition groups with the control groups and tested by the Dunnett's +/- statistic. A test for homogeneity of variances was used (Dunnett F) to determine whether to consider the pooled variance estimate or separate variance estimate for the specified contrasts. The analyses were performed on the IBM 360 computer using the SPSS ONEWAY Package (Nie et al. 1970).

96. Standard statistical calculations (e.g., means, standard errors, etc.) were also performed with the aid of the IBM 360 computer. Graphical presentations were facilitated by means of Tectronix plotting software in conjunction with the IBM 360 computer.

97. Ordination analysis was performed on total monthly nekton collections to aid in the determination of the effect of disposal on the offshore fish fauna. It was believed that changes might be observed due to avoidance or attraction of species of communities. Ordinations were used to summarize relative changes between sites and between pre- and postdisposal periods at individual sites.

98. A similarity/dissimilarity index was used to reflect community relationships and/or change within communities. These methods were also used to evaluate the feeding behaviors. In this case the food intake of all individuals was combined and treated in a manner similar to a benthic collection as described in previous sections of this report.

99. All calculations were compared by discriminate analysis techniques and computed based on a $P \leqslant 0.05$ level. Routine calculations (means, species diversity, etc.) were done on a Burroughs 5500 computer utilizing packaged routines available at John Carroll University.

Chemical Studies

100. The chemical phases of the project were the responsibility of the GLL. Components included the analysis of water and sediment (solid and interstitial phases) as well as elutriate tests.

Sampling and Profiling

101. Water generally was collected in replicate using 8.2 ℓ Van Dorn water bottles at PW1-11 in 1975 and PW1, PW2, PW3, PW5, and NDS in 1976 (Figure 2). The only exception was during the 1976 disposal events when pump samples were simultaneously gathered from three depths while the hopper dredge released the dredgings within 100 m of where the R/V C. A. Dambach was anchored. Conductivity, pH, turbidity, and dissolved oxygen were continuously measured in the continuous flow monitoring system which is described in Appendix B. Dissolved oxygen, temperature, and

conductivity profiles were made each time a Van Dorn collection was gathered. Sediment-water interface samples were taken from the top of the box corer at C1 through C4 and SD1 through SD16 on 15-16 May, 10-11 June, and 7-8 July in 1976. Each was analyzed for pH, D.O., and the soluble fraction of SiO_2, PO_4-P, NH_3-N, TOC, Fe, Hg, Zn, and Mn.

102. Sediment was collected using a General Oceanographic spade box corer with a sampling area of 151 cm^2 and tube lengths of 30 cm in 1975 and 40 cm in 1976. Four replicates were taken at each station in 1975 (C1 through C4 and D1 through D12 on Figure 1) and two in 1976. In 1976 Stations SD1-SD16 (Figure 6) were sampled along with Stations D2, D3, D8 and D9, as well as C1 through C4 (Figure 1). Splitting, preservation, and interstitial water separation procedures also are described in Appendix B. However, during the Initial Survey (11-12 June 1975), the duplicate sediment samples were gathered with a Ponar grab because the box corer had not been received.

Water Analyses

103. Splitting, preservation, and analysis of water for the variables measured in 1975 and 1976 are shown in Table 4. Several 1975 variables that did not appear to yield results meaningful to the study were eliminated in order to save both time and money. The quality control procedures employed through this investigation also are described in Appendix B.

Sediment Analyses

104. Shipboard determinations of pH, temperature and dissolved oxygen were made on approximately 250 mℓ of interface water removed from the corer. The centrifuged, filtered, and preserved samples were analyzed for ammonia, TKN, DOC and orthophosphorus.

105. The procedure for subsampling and maintaining the subsamples in a nitrogen environment at 4° C is described in Appendix B along with the splitting of the subsamples and separation of the interstitial water. The sediment and interstitial water variables analyzed during 1975 and 1976 are shown in Table 4.

TABLE 4

Variables Determined for Lake Water, Interstitial Water, and Sediment Chemistry on Samples Collected in Lake Erie off Ashtabula, Ohio

Sample Type	1975	1976	Sample Type	1975	1976	Sample Type	1975	1976
Lake Water	Alkalinity	SS	Interstitial Water	TOC	TOC	Sediment	pH	pH
	SO_4	pH		TKN	NH_4-N		Eh	Eh
	SiO_2	PO_4		NH_4-N	PO_4-P		Percent H_2O	Percent H_2O
	NH_3-N	Total-P		PO_4-P	Fe		TOC	TOC
	TKN	NH_3-N		Fe	Mn		Percent clay	NH_4-N
	NO_3-N	SiO_2		Mn	Hg		Percent silt	Fe
	NO_2-N	POC		Hg	Zn		Sand fractions	Mn
	PO_4-P	Fe		Cd	Cl		TON	Hg
	Total-P	Mn		Cu			NH_4-N	Cu
	DOC	Hg		Ni			Total-P	Zn
	POC	Zn		Pb			CEC	Grain size (-1 to 9 ϕ units)
	Cd	Cl		Zn			Cd	
	Cu	Turbidity					Cu	
	Fe	DO (profile)					Fe	
	Mn	Temperature (profile)					Hg	
	Hg	Conductivity (profile)					Mn	
	Ni	Percent transmission (profile)					Ni	
	Pb						Pb	
	Zn						Zn	
	pH							
	Eh							
	DO (profile)							
	Temperature (profile)							
	Conductivity (profile)							
	Percent transmission (profile)							

The analytical and quality control procedures are presented in Appendix B.

Elutriate Analyses

106. Sediment as well as Dredge Site and Disposal Site waters were collected and prepared for standard elutriate tests (Keeley and Engler 1974) on 31 July 1975 (three Harbor and three River) and 15 May 1976 (five River). The 1975 variables included TOC, TKN, ammonia, nitrite, nitrate, orthophosphorus, Fe, Mn, Hg, Cd, Cu, Ni, Pb, and Zn; 1976 analyses were done for TOC, ammonia, orthophosphorus, Fe, Mn, Hg, and Zn.

Heavy Metal Determinations in Fish and Benthos

107. Quantitative determinations for Hg, Fe, Pb, Cd, Cr, Ni, Cu, and Mn were made on a total of 163 fish encompassing 14 species that were collected with gill nets at six sites (NDS, D2, D8, F11, F18, and F28) 10 days prior to as well as 5 and 30 days after the 1975 and 1976 dredged material disposal operations. Capture, preservation, and analytical procedures are described in Appendix C. Benthos were gathered with a box corer at Stations C1, SD6, SD7, SD10, and SD11 during the same three 1976 cruises as described for the heavy metals in fish determinations. In addition, benthos were gathered in a similar manner from a station at the mouth of the Ashtabula River and a second station 0.6 km upstream from the River mouth. A total of 138 benthic macroinvertebrate samples were split into major taxa (oligochaetes, chironomids, amphipods, isopods, leeches, sphaerids, and gastropods) and analyzed for Fe, Mn, Cu, Cd, and Zn. Mercury analyses also were done on 14 samples of oligochaetes from the above benthos collection sites visited during the 5- and 30-day postdisposal samplings. The Hg analyses were limited because it required a larger volume of benthos than did the tests for the other heavy metals. The preparation and quantification procedures are detailed in Appendix C.

Statistical Procedures for Analyzing Chemical Data

108. Elutriate chemistry results were subjected to Kruskel-Wallace non-parametric analysis of variance.

109. Water, interstitial water, and sediment data were sub-

jected to statistical tests to determine their normality and homoscedasticity. A Chi-square test was used to check for normality and a Bartletts Test for multiple groups was employed to test for homoscedasticity. The table was assumed to be normal and homogeneous unless the Chi-square value and Bartletts Chi value were significant at the 0.05 α (alpha) level at the specific degrees of freedom. If the table was not normal and homogeneous, it was subjected to a transformation and then retested.

110. The normal and homogeneous (raw or transformed) data tables were then subjected to an analysis of variance test. The GLL used a one-way nested analysis of variance (ANOVA) design to analyze the data. This design was particularly suited to these data as the sampling scheme involved randomly selected replicate samples at stations which were nested within predetermined sub-areas.

111. The data were then graphically displayed with a solid line indicating means and intersection bars indicating each mean's confidence interval. As graphs were produced, they were compared to the nested ANOVA results. In the cases compared, the results from the ANOVA matched those given by the graphical display. Further ANOVA testing was based upon the results of the graphic displays. That is to say that obviously nonsignificant differences were not further tested via ANOVA.

112. One graphic data presentation showed both long-term (Reference and Disposal Sites at both predisposal and postdisposal dates) and short-term effects (Reference vs. Disposal Sites at the same date) for a parameter at one depth. The mean and confidence interval graph was used for the great majority of the data, and the nested ANOVA was employed to confirm and check the graphic results.

113. To summarize, the GLL used means and confidence intervals that were displayed graphically to examine the impact of dredging and disposal as determined through chemistry parameters. For sediment and interstitial water in the 1975 phase, one graph consisted of the Reference Area, the River Dredging Area, and the Harbor Dredging

Area at all the cruises before and after disposal for the parameter at any one depth. For Lake water in the 1975 study the graphs were done somewhat differently. Since no short-term effects (i.e. no difference between the Reference Water Sites PW1, PW2, and the Disposal Sites PW3, PW4, or PW5 and PW6 at the same cruise) were found via ANOVA, only the longer term predisposal vs. postdisposal effects were displayed. A graph consisted of one mean and confidence interval for all PW stations, regardless of location, for each cruise. A graph displayed both the surface and bottom values for one parameter.

114. In the 1976 phase, sediment, interstitial water, and interface water parameters were displayed in the same manner as for the 1975 study. One graph showed the Reference Area and Disposal Area for all four 1976 cruises for a parameter at one depth. Lake water data from 1976 were handled in the same manner as for the 1975 Lake water data. Other statistical handling of data via discriminant and multiple regression analyses was performed according to the Statistical Package for Social Sciences (SPSS) routines by Nie et al. (1970).

115. To ascertain possible relationships between biological, chemical, and physical variables measured during the 1975-76 study, each variable was correlated with every other variable. Correlation values were calculated with the aid of a multiple regression analysis program within the SPSS package (Nie et al. 1975). The Pearson Product Moment correlation coefficient was computed by taking the square root of the coefficient of determination.

PART IV: RESULTS AND DISCUSSION

116. A detailed presentation and discussion of the biological, chemical, and physical results from the Ashtabula Study can be found in Appendices A-C. The following is an attempt to summarize the information gathered prior to, during, and after the two disposal operation periods, August 1975 and May 1976. This study in part is a response to the International Working Group on the Abatement and Control of Dredging Activities, a joint Canadian and United States Federal Governments committee, which recommended that research should be conducted to more rigorously define the specific nature of impacts relating to nutrients and potentially toxic substances that allegedly are released as a consequence of dredging-related activities.

Physical Studies

Bathymetry and Subbottom Profiles

117. A bathymetric chart of the study area for July 1975 is presented in Figure 7. The study area can be divided into four distinct topographic regions: (1) a relatively smooth control area with a low relief of approximately 1 m/km, (2) a terrace with two depressions immediately to the north of the Control Area (this terrace has a grade of 0.5 m over 1 km and strikes from northeast to southwest), (3) a Disposal Area to the east of the terrace characterized by rugged topography as a result of earlier disposal, and (4) a smooth, gently undulating topography beyond the 18.0-m isobath that slopes gradually towards the Lake center (1 m/km).

118. The bathymetry data were compared with depths in the same area presented by Herdendorf (1967). No obvious differences were observed.

119. Another chart was compiled for September 1976 (Figure 8) to see if significant changes had occurred since the 1975 survey.

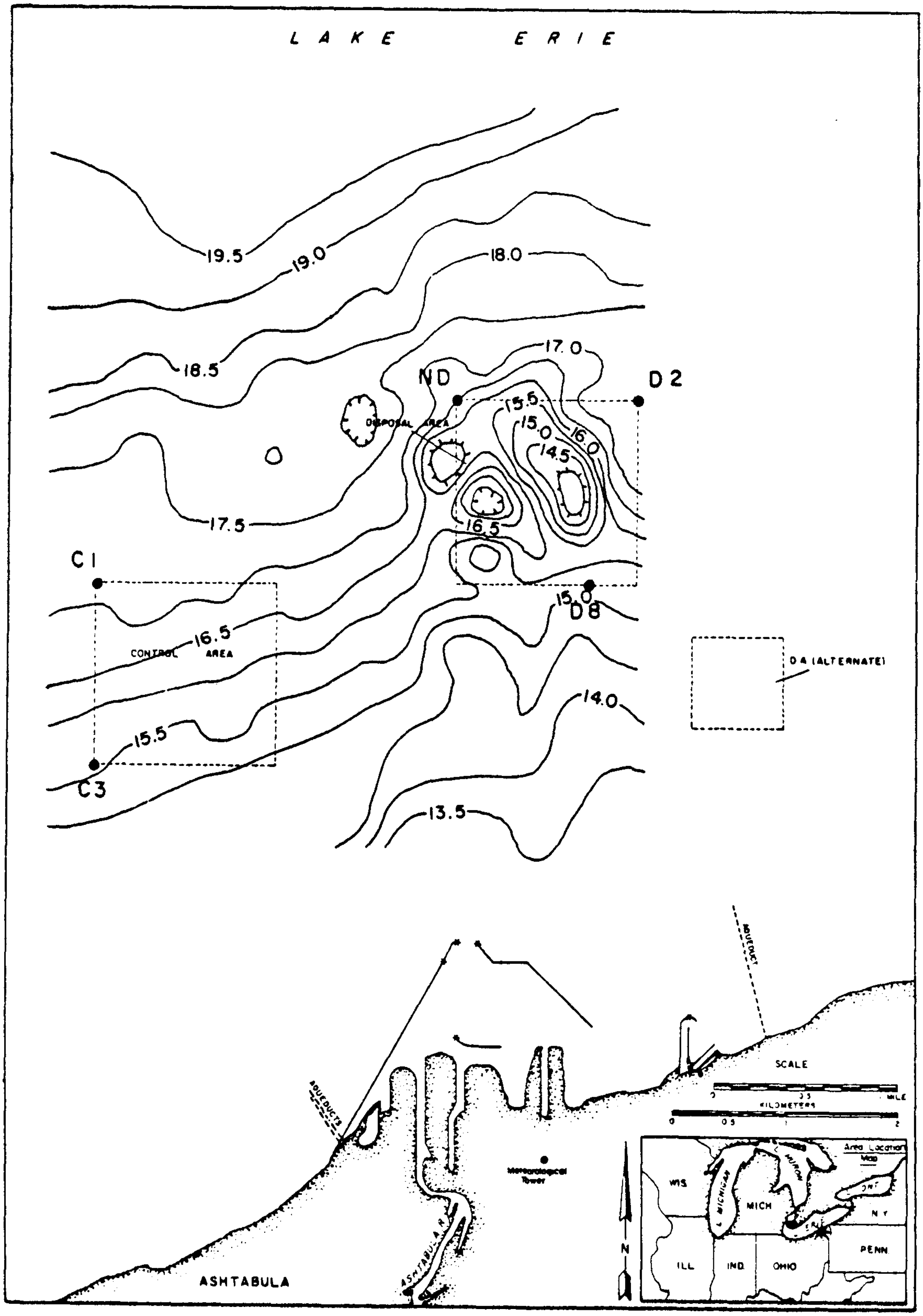


Figure 7. Large-scale bathymetry for July 1975, depth contours are in meters

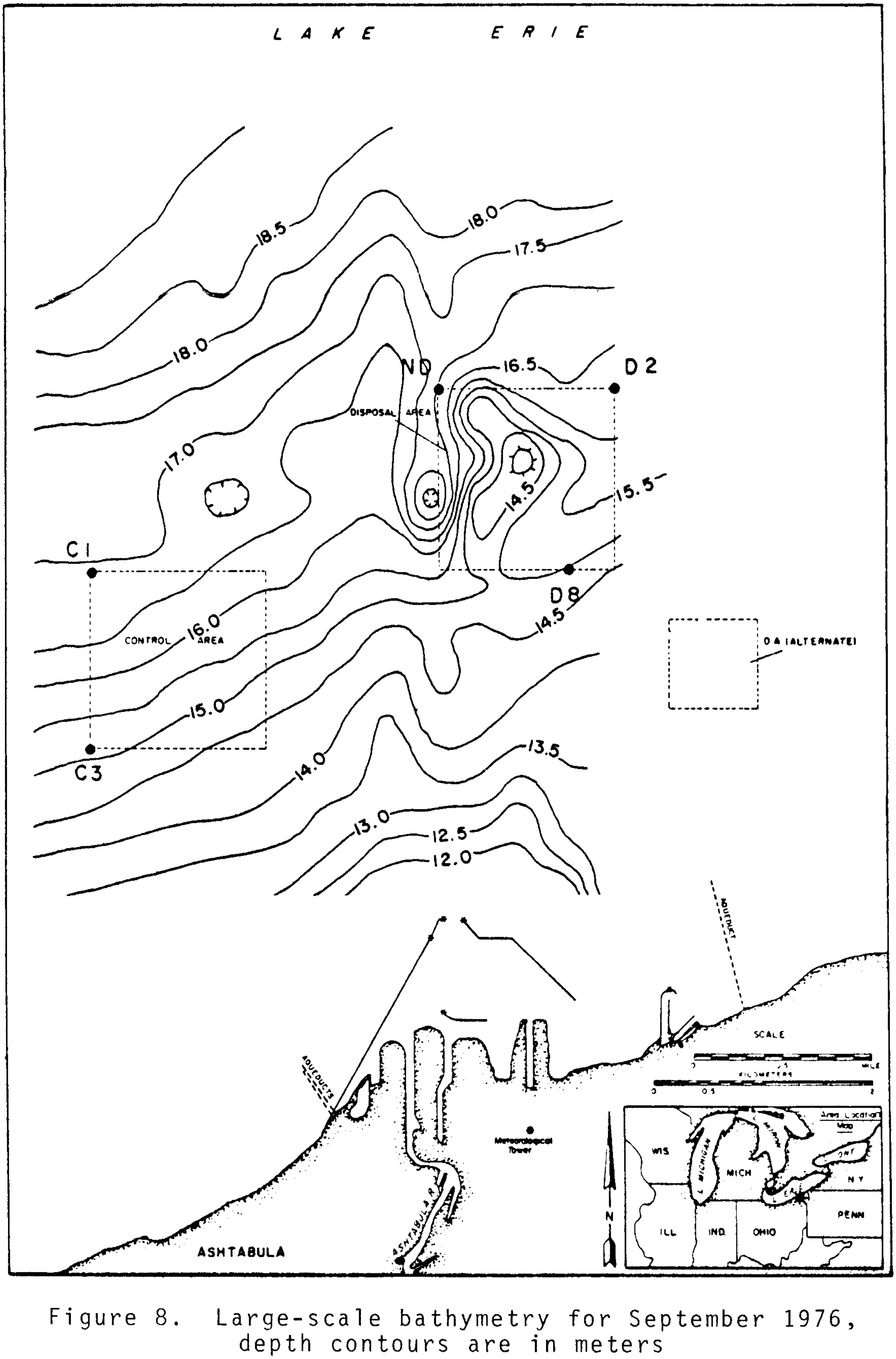


Figure 8. Large-scale bathymetry for September 1976, depth contours are in meters

A comparison of these two charts revealed that the general trends in the bottom configuration were approximately the same during the two surveys. There does, however, appear to be a relatively systematic difference of approximately 0.5 m between the two charts that cannot be accounted for. Consequently, emphasis was placed on relative depth differences over the study area for each survey when comparing the two charts. Both surveys showed a mound near the center of the Disposal Area and a basin near the western edge. Discrepancies between the contours were probably the result of the coarseness of the sampling grid rather than actual sediment height. The disposal operations in 1975 and 1976 seemed to have little discernable effect on the bathymetry of the area.

120. The sediment piles created by the disposal operations were only 30 to 50 cm high as measured by both rods and electronic bottom scanning. Disposal created numerous small piles within the Disposal Area rather than a single mound. The small piles in the 1975 disposal were recognizable through April 1976 but not discernable by June 1976. A more detailed discussion of bottom profile changes is presented in the Sedimentology Section of this report (paragraphs 145-160).

121. No natural erosion or deposition of sediment could be detected within the Reference Site. Subbottom profiling as well as cores from the latter indicated that the sediment was heterogeneous but the fine sand and silty layers were thin.

Currents

122. The average current speed measured at the 3-m level above the bottom was 12 cm per sec. while it was 5 cm per sec. at 1 m above the sediment. The flow direction at both levels generally was parallel to the shore and generally uniform at the same depth over the entire study area. The large-scale circulation of Lake Erie was the dominant factor. However, longitudinal seiches, which had a period of 14 hrs, accounted for most of the periodic northeasterly (most commonly observed) and southwesterly flows. Lunar tides and inertial currents

were observed along with transverse seiches but these had a lesser impact on the sediment.

123. Current speeds were greater at the 3-m than at the 1-m level. For example, in 1975, 7% of the measurements exceeded 26 cm per sec. at the 3-m depth, while only 3% did so at the 1-m level. In fact, only 2% of the time were readings above 12 cm per sec. observed at the 1-m level. There was a perceptive drop in the current speed between February and March 1976, which was attributed to a cold air layer at the water-air interface that greatly reduced the wind drag on the surface water.

124. Sudden changes in speed and direction of the currents generally coincided with wind events. Flows in excess of 50 cm per sec. were recorded during the latter. It was during such events that the most dramatic erosion of the disposal mounds occurred.

Water Temperature

125. Temperature readings from the 1- and 3-m levels above the bottom showed that a thermocline was present from June through September 1975. During the August 1975 disposal period, the thermocline oscillated between the 1- and 3-m levels primarily as a function of internal waves. The August 1975 epilimnion ranged from 24 to 26° C while the hypolimnion was 13° C. In September turnover occurred which resulted in a fairly uniform 20° C water column. The temperature, while remaining unithermal, declined to 15° C in October, 11° C in November 1975, and 4° C in March 1976. No stratification was present during the 1976 disposal period. A weak thermocline was observed in June 1976 but strong winds prevented thermal stratification from occurring until late July. While no data were gathered in August 1976, a thermocline at 1 m above the bottom was noted in September.

126. During disposal, a short-lived increase of < 2° C was observed. When the dredgings were released when the water was stratified, the thermal structure remained intact.

Transmissivity

127. The first transmissivity readings taken on 1 August 1975 revealed that the profile was quite similar to the vertical profile of the temperature. The values were relatively constant with a transmissivity of about 20% in the epilimnion, but at the thermocline, there was a sharp decrease to about 6% for the 1-m layer between the bottom and the thermocline. This increase in turbidity in the hypolimnion was associated with the density discontinuity produced by the thermocline. Resuspended sediments could not migrate through the thermocline because of the relatively large amount of energy required to overcome the density gradient. Only under storm conditions when there was sufficient energy to break down the thermocline could the resuspended sediments mix freely throughout the water column. Also, the thermocline was a natural collection zone for settling organic matter that greatly decreased the transmissivity.

128. The transmissivity generally increased with distance offshore with the surface values varying from 14%, 1/2 km north of the Harbor entrance, to 22% for the farthest station offshore, 2 km north of NDS. The shallowness of the water column that allowed for penetration of the wave energy for sediment resuspension as well as nearness to the breaker zone and longshore currents were probably the major causes for the decrease in transmissivity near the Harbor mouth. The Ashtabula River discharge was very low for this sampling period so it affected the transmissivity to only a limited extent. The Harbor, however, was continually agitated by shipping activity, and diffusion of the turbid water to areas outside the Harbor might have influenced the transmissivity in the nearshore zone.

129. The transmissivity increased in the middle of August 1975 to surface values as high as 39% although the nearshore station was still quite turbid. By the middle of September 1975, the values dropped sharply to < 10% with the nearshore station displaying a transmissivity of < 1%. This sampling interval

followed a period of heavy rains and high river discharge that affected the values. The nearshore station was most affected by the increased River discharge, but it was difficult to tell if the other stations were affected by the River plume or just by the increased wave and current activity associated with the rainstorms.

130. The measurements in October 1975 showed that the transmissivity was uniform throughout the water column with values between 10 and 13%, but in November the readings at all stations dropped to zero. These measurements were taken 2 days after a storm on 14 November in which wave heights reached 2 m and current speeds reached over 40 cm/sec, resulting in resuspension of sediments. A similar rapid change in transmissivity was observed by the diver during the September 1976 sampling. He reported visibilities of between 2 and 3 m before a storm, but the visibility dropped to zero after the storm.

131. The strong susceptibility of the transmissivity values to previous meteorological conditions makes it difficult to characterize the values by seasons since the time of sampling relative to the last storm greatly influenced the readings. As a general rule, though, the transmissivity was fairly uniform with depth during the unstratified seasons. Transmissivity decreased below the thermocline during thermally stratified seasons and dramatically decreased following storm conditions. Consequently, it is apparent that there was considerable natural variation in the transmissivity, and the changes were closely associated with a thermocline, storm activity, and water depth.

132. Transmissivity readings taken during the 1975 disposal operation revealed maximum turbidity at 8 and 13 m below the surface. The 8-m material was believed to be fine-grained sediments while the lower plume appeared to be confined to the hypolimnion by the thermocline. Problems in ascertaining the relative position of the moving vessels that were attempting to measure the extent of the plume prevented the determination of the plume

movement following each disposal event. Based on measurements from the anchored craft, the plume traveled at between 20 and 40 cm per sec. In 1976, when the water was not temperature-stratified, the plumes were found near the surface and consisted primarily of fine-grained material. This generally settled out within 12 min and extended for approximately 100 m from each Disposal Site. A brownish cloud of very fine-grained material was visible from airplanes flying over the Disposal Area, but this plume could not be detected by the in situ measuring devices.

Waves

133. Waves were measured to determine the wave climate of the study area and to provide an estimate of the degree to which wave action affected sediment resuspension and transport. The wave gauge successfully recorded water-level fluctuations for 10 periods averaging about 21 days each with 6 sampling intervals of 10-min duration per day. The significant wave heights were calculated for each sampling interval along with time of observation, wave period, maximum wave height, wind speed, and an estimation of the magnitude of the wave's orbital velocity near the bottom at the Disposal Site. The significant wave heights also were plotted. The wave periods were generally between 4.5 and 6.5 sec.

134. The recorded wave periods were higher than expected because the shorter period waves could not be measured with a pressure sensor located in such deep water. Short-period waves attenuated more rapidly with depth than longer period waves so the results were biased in favor of higher periods. The tabulated results were computed from the detectable pressure fluctuations in 17 m of water at the Disposal Site, which excluded the detection of waves with periods shorter than 3.5 sec. Therefore, care must be taken when examining the wave results because they are not an exact description of the actual water surface fluctuations, but rather a theoretical estimate.

135. The wave gauge was located in shallower water (9 m) during October and November 1975. The measured pressure fluctuations were larger than those measured in deeper water because

there was less attenuation due to water depth. However, the wave heights computed from the pressure fluctuations were comparable to those calculated from measurements taken in deeper water. Therefore, all wave height values were assumed to be representative of the waves that were present at the Disposal Area.

136. The majority of the recorded waves were < 1 m, which is typical for waves on the Great Lakes. During storm conditions the significant wave heights frequently reached nearly 2 m with maximum waves greater than 2.5 m. The largest waves were measured during November 1975, which was a direct result of the higher wind speeds during that month. There were two storms in November, one on the 14th and one on the 30th. In both cases the hourly wind speeds averaged > 13 m per sec and waves of nearlv 2 m were generated. There were also several other storms that produced large waves (e.g., on 24 September 1975, 19 May 1976, and 7 June 1976) and in most cases, a gradual buildup of the wave field was observed. The waves typically increased for about 20 hrs before they peaked either at or slightly after the peak of the storm. Then they slowly subsided with the passing of the storm.

137. The oscillatory water-particle motions of the waves usually diminished to < 1 cm per sec at the bottom. This value increased considerably under storm conditions. During the storm of 14 November 1975, the magnitude of the orbital velocity at the bottom averaged over 10 cm per sec for a 24-hr period. On 1 December 1975, the speed reached 20 cm/per sec for a short time. These motions were qualitatively confirmed by the diver who could easily feel the oscillatory motions at the bottom while diving during a period of 1.0- to 1.5-m waves.

138. The high speeds at the bottom due to waves did not occur very often, but they could be instrumental in resuspending sediments. The speeds were not great enough alone to resuspend the sediments, but when superimposed with the ambient currents,

they could easily add enough energy for sediment resuspension. Assuming that an erosion velocity was 20 cm per sec, then a 10 cm per sec component from the wave field in conjunction with a 10 cm per sec current speed would provide sufficient energy for sediment resuspension. Of all the OV measurements made, 2% were > 10 cm per sec. However, during November, 8% of the measurements were > 10 cm per sec, which indicates that November might have been the most active month for sediment erosion.

139. During the 1976 disposal event, sensoring equipment was operated aboard the Dambach while the dredge Hoffman deposited dredging loads from 25 to 100 m from the anchored research vessel. Shock waves with internal oscillations as high as 70 cm per sec passed by the Dambach at a rate of 20 to 40 cm per sec. These internal waves generally diminished within a few minutes; but, in one instance, aftershocks persisted for 10 min. As noted in a later section, the short-term "pulses" could be detected in the pH and conductivity values observed using continuous-flow monitoring devices.

Meteorology

140. The predominant wind direction at the site during the June 1975 through December 1975 period and during the March 1976 through September 1976 period was from the south with a secondary flow from the west. The predominant wind speed class was the 1.8 to 3.6 m per sec class. Fifty percent of the hourly averaged wind speeds persisted for 2 hrs or less and 90% persisted for 8 hrs or less. The maximum observed wind speed was 13.4 m per sec on 10 November 1975. The event coincided with a period of active erosion at the Disposal Sites.

141. In general, the meteorological data collected on-site indicated that the site area was typical of a shoreline environment. This was evident from the fact that the range of temperature was not as great at Ashtabula as it was at stations located farther inland. For example, during the period from July 1975 through June 1976, the daily maximum temperature value at Ashtabula (located

about 1 km from the Lake Erie shoreline) averaged about 1.7° C cooler than that at the Cleveland National Weather Service station. The daily minimum temperature at Ashtabula was 1.2° C warmer than at Cleveland.

Hydrology

142. Hourly Lake-level values were taken during the periods when bathymetric surveys were conducted and daily average Lake levels for the entire period of the study were computed. Since the study was located approximately midway along the major axis of the Lake, the water-level fluctuations were not as great as those typically observed at the eastern or western ends of the basin. The maximum recorded water level during the study period occurred in June 1976 and was 573.83 ft.; the minimum was 570.02 ft. and occurred in November 1975. The water level was lower during the winter months with January 1976 recording the lowest monthly mean level at 571.70 ft. The maximum monthly mean occurred in May 1976 with an average water level of 572.93 ft.

143. The largest Ashtabula River discharge values occurred during the winter months due to melting snow and aquifer discharge, with the greatest rate of 107.89 m^3/sec occurring in February 1976. The greatest daily discharge of 22.99 m^3/sec during the summer months occurred at the end of August 1975 following a heavy rainstorm.

144. Estimates of the total suspended sediments (TSS) discharged by the Ashtabula River were made using the River discharge values. Beginning in 1969, TSS values were measured by the USGS at a location 8 km upstream from the Ashtabula Harbor. However, measurements were discontinued by USGS in 1973. Therefore, direct measurements of TSS for 1975-76 were not available, and the values were estimated from a TSS-River discharge relationship. The TSS values from 1969 to 1973 were plotted against River discharge Q and a curve was fitted to the data using the least-squares method. The relationship between TSS (tons/day) and the Ashtabula River discharge Q (cfs) was determined to be:

$$TSS = 0.00104\ Q^{1.704}$$

This equation was then used to estimate the sediment loading of the River. Estimated TSS values were computed for the days when transmissivity measurements were made. The TSS values for these days were extremely low with the maximum being only 2.37 tons/day. With such low values it was quite unlikely that the Ashtabula River affected the transmissivity at the Disposal Area.

Sedimentology

145. In 1975 graduated steel rods were installed in the Lake bottom at Disposal Stations D2 and D8 and at Reference Station C1. On 14 August 1975, after dredging had ceased, no sediment accumulation was observed at C1, but 45 and 37 cm of new sediment were found at D2 and D8, respectively (Figure 1). The rod at C1 was lost after this date, so no further control data were available. On 15 September, decreases in the heights of these mounds of 5 cm at D2 and 3 cm at D8 were observed. The rod at D8 was lost in October, but the one at D2 showed 40 cm in October and only 30 cm on 11 November. A severe storm that occurred on 10 November might have eroded a portion of the sediment pile. Diver observations of the Lake bottom at the Disposal Sites indicated a very silty bottom after disposal until November, at which time the bottom appeared to be more compact and slightly hummocky. This suggests that the November storm with its associated strong currents and wave activity had eroded nearly 10 cm of silty sediment from the pile at Station D2.

146. The survey rod data from NDS for June 1976 showed that a very flat, cone-shaped pile with a height of only 36 cm had been deposited near the center of the Disposal Area. The sediment trap data showed similar results although the values were slightly less. The accumulated sediment values were integrated over the 160,000 m^2 grid area for both the survey rod data and the trap data in order to estimate the total volume of sediment. The results from the survey rods showed that approximately 18,000 m^3 had been deposited, and the trap data indicated that only about 14,000 m^3 of sediment had settled into the area within the 400-m square centered on the Disposal Site. Percent water

content measurements of the sediment indicated that approximately 49% (by weight) of the sediment pile was water. Assuming a water density of 1.0 g/cm^3 and sediment-particle density of 2.6 g/cm^3 (quartz), the survey rod data indicate that 1.67×10^{10} g of material fell into the study area. The records from the Corps dredge Hoffman show that 2.41×10^{10} g of material were discharged at the Dispoal Site, which means that approximately 70% of the discharged material settled into the 160,000 m^2 area. Factors that would contribute to this apparent discrepancy are: (1) inaccurate methods of estimating hopper loads, (2) transport of suspended sediment out of the study area before it could settle to the bottom, and (3) rough weather that prevented the dredge from discharging the material directly over the designated site.

147. In order to assess the changes in the thickness of the pile that occurred between June and September 1976, the differences in the monthly readings were calculated and plotted for both the survey rods and sediment traps. Occasionally, there was an increase in the level of accumulation in some of the traps, mainly due to uneven distribution of the sediments within the eight collection tubes at each trap. Generally, the increases were only about 0.5 cm but sometimes 2- to 3-cm increases were observed.

148. Many of the survey rod and sediment trap readings showed a decrease in the sediment accumulation due to erosion and compaction. Compaction may have occurred at Station D10 where a decrease of about 11 cm was observed in the traps. A 5-cm decrease on the survey rod at Station D3 between June and July was attributed to erosion because scour features were observed by the diver. Ripple marks observed at some of the other stations also suggested erosional activity. Definite trends of scour and fill, however, were not apparent as the changes in the sediment pile were so small. Compaction in the sediment traps was not readily discernible either. The changes in the sediment levels in the traps at most locations were so

small that the accuracy of the sampling method precluded further analysis of compaction rates.

149. During the installation and retrieval of sediment traps at each station, the diver recorded a description of the Lake bottom. In general, the Lake bottom was flat at all three Disposal Sites, but piles of the old dredged material were frequent nearby.

150. Sediment shear strength measurements were taken at several depths in order to determine the compaction of the sediments. Shear strengths generally were weakest at the surface and generally increased with depth. However, occasional sand lenses in both the natural and deposited sediment resulted in low values at random depths. No sharp change was observed near the interface between the deposited and "natural" material.

151. Radiographs and x-ray scans did indicate that there was a continuity between the original Lake bottom and the dredged material. The amount of dredged material observed in the cores compared favorably with the amount measured with the sediment traps and survey rods. For example, in June the survey rod showed 27 cm of sediment at Station D10 and the radiograph of a sediment core taken at the same location showed about 23 cm of new sediment. In general, the measurements from the sediment cores were slightly less than the values obtained from the traps and rods. This was due, in part, to compaction that occurred when the cores were collected as well as additional settling during transport. Rhythmic deposits of sand and mud lenses were found in the bottom sediments, but they were not nearly as prevalent as in the dredged material. This was expected as the dredged material was deposited from several discharges, which produced graded bedding. This grading was evident in most of the cores where alternating rhythmic bands of sand layers with overlying mud were observed. The dredged material was clearly distinguishable from the original Lake bottom sediments because of its high content of plant debris, cinders, coal fragments,

and iron pellets, and because of density changes due to the cyclic deposition of the sediments.

152. The grain-size distributions of samples taken from sediment cores were measured by the Great Lakes Laboratory using the F.A.S.T. technique. Because of errors in the measurements, the sum of the constituents of the samples, in most cases, was not 100%. The largest discrepancies occurred in the 1975 data as 40% of the samples were off by more than 2% and 13% of the results were off by more than 5%. The largest discrepancies were approximately 8%. It was probable that the error occurred in estimating the silt fraction of the sample, so the silt fraction was adjusted such that the sum of the constituents was within 2% of the original sample weight. This was done on the worst cases as a test to see how this error would affect the results of the statistical analysis. No appreciable change in the results was obtained with such adjusted data for worst cases. Therefore, no further attempts were made to force the data, and the original data were used in all analyses.

153. The grain-size distributions of the sediments, which were measured from sediment cores collected at the Reference Sites and near Disposal Stations D2 and D8, were first plotted as weight percent versus grain size. Seven grain sizes were used in the analysis, and results were based on the mean of four replicates. Any variability within the replicates was not investigated.

154. The results of the grain-size distributions showed that the sediments at the Reference Sites were bimodally distributed (perhaps two overlapping normal distributions). The sediments consisted of about 45% silt, 45% sand, and 10% clay at all Reference Sites. Only minor variations were observed in the distributions with both time and depth. Most of these variations were probably caused by sampling from slightly different sites as it was difficult to sample at exactly the same spot. The distribution curves for 1976 are different from those for

1975 because 11 grain sizes were analyzed in 1976 compared to 7 in 1975. However, the total percentages of sand, silt, and clay remained fairly constant at the Reference Sites between 1975 and 1976.

155. The data collected near the Harbor Material Disposal Stations D1 to D6 showed that there were some changes in the grain-size distributions following the disposal operation. There were no obvious trends in the variations of the distributions but rather apparently random changes. For example, at D1 and D2 there was an increase in fine sand, but at D3 there was generally a decrease in fine sand following the disposal operation (Figure 1). These results indicated that there were probably several local pockets of deposited sediments resulting from inhomogeneities in the dredged material that produced the variable results. Such variations were observed in the radiographs as well as visually in the sediment cores. There were also changes in the sediment distributions in the months following the disposal operation, but again no generalization could be made on the basis of the grain-size distribution plots.

156. The results of the grain-size distribution curves made from data collected near Disposal Site D8 (Stations D7 to D12) were similar to the results obtained near Site D2 (Figure 1). There were frequent changes in the grain-size distributions following the disposal operation, but no trends in the variations were apparent except for a general increase in fine sand at most stations.

157. Sediment cores that were taken in 1976 were also analyzed for grain-size distribution. In order to study the sediment distribution with depth and in order to compare the Reference Area with the Study Area, long sediment cores (approximately 50 cm long) were taken at Station C3 and at trap locations SD8, SD10, and SD12, located at NDS. Based on the sedimentation rate for Lake Erie, these cores represented approximately 200 to 250 yrs of sediments. The cores were sectioned at approximately 5-cm intervals, and the sediments analyzed

for texture. For comparison, the results of Reference Site Stations C3 and SD10 were plotted (Figure 1). The results showed that the grain-size distributions varied considerably at both sites, even over short depths. In general, the sediments at Station C3 had a higher silt content than at SD10. The sediments at NDS were usually bimodal with more sand than silt.

158. The multivariate analysis of variance performed on the 1975 grain-size distribution data showed that the data at the Experimental Stations did not change in a similar manner as the data at the Reference Sites. This indicated that the disposal operation produced statistically significant changes (significance probability < 0.05) in the sediment grain-size distribution. The univariate analysis of variance indicated that the clay-sized material was very important in producing the significant interaction. To illustrate the changes that occurred, the mean concentrations of sand, silt, and clay were plotted along with the associated F-value probabilities. The November data were also plotted but were not used in the statistical analysis. The plots showed a large drop in the clay at the experimental stations following the disposal operation. This change accounts for the importance of clay in contributing to the significant interaction of the multivariate analysis between the Control Stations and the Experimental Stations. The decrease in clay is physically possible as much of the clay was probably stripped from the dredged material as it fell to the bottom. The plots also showed an increase in silt near Disposal Stations D1 to D5 that was probably caused by discharging silt-rich Harbor sediments in that area.

159. As a result of the different sampling grid and the collection of two rather than four replicate samples, the statistical methods used to analyze the 1975 data had to be modified for the 1976 data. In order to determine statistically if the spatial distribution of the sediment grain size changed significantly because of the disposal operation, a discriminant

analysis program BMDP7M was used. In order to compare the May and June data, the values from 15 sampling locations near NDS were used as replicate samples for the discriminate analysis. The results indicated that there were significant differences between the May and June data. The conclusion was that the dredged material was different than the original Lake bottom with respect to grain-size distribution as there was a definite separation between the predisposal data and the postdisposal data for 1976.

160. The SEDMOT plots revealed that no significant movement took place in July or during the disposal operation because of low velocities but that sediment transport occurred frequently from late August 1975 to May 1976. Most of the transport was either in a northeasterly or in a southwesterly direction, which indicated that it closely followed the topography and the shoreline. The results showed that the eroded material could have theoretically traveled several kilometers before it settled out of the water column. The results also showed that the range of sediment sizes that were transported was from fine silt to coarse sand with medium sand being the most abundant within the area studied outside the disposal sites. There were no recorded episodes of sediment transport between June and September 1976.

Biological Studies

Phytoplankton, Chlorophyll *a*, and Primary Productivity

161. The changes in the phytoplankton total number and group composition as well as in chlorophyll *a* and primary productivity as observed for the Reference Site Stations PW1 and PW2 are shown in Figure 9. The patterns, including the lack of correlation between cell numbers and chlorophyll *a*, were typical of those noted for the Lake Erie Central Basin (Munawar and Burns 1976).

162. During the 1975 disposal operation the observed differences between the chlorophyll *a*, phytoplankton total

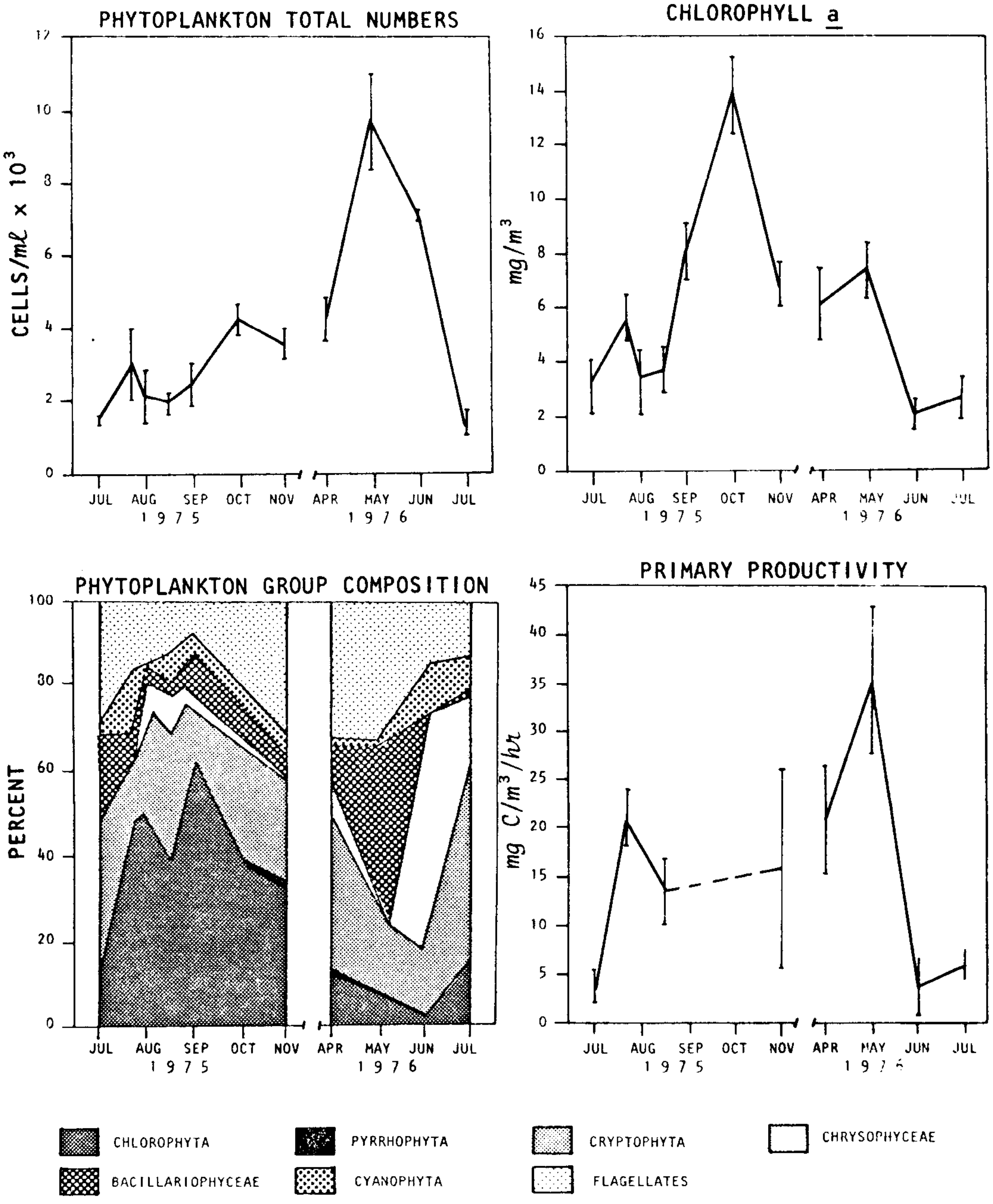


Figure 9. Mean temporal variation in surface phytoplankton total number, group composition, chlorophyll a concentrations, and primary productivity for reference sites PW1 and PW2, 30 July 1975 to 8 July 1976. Bars indicate 95 percent confidence intervals for means

numbers, and phytoplankton group composition at the Reference Sites and those areas believed to be impacted by the disposed dredged materials were statistically similar, particularly when the patchiness of Lake Erie phytoplankton is considered.

163. With the exception of somewhat higher chlorophyll a and primary productivity values in the nearshore waters (Stations PW8 and PW9), which as indicated by chemical and physical measurements were not impacted by the disposal operation during the 1975 5-, 30-, 60-, and 90-day postdisposal samplings, and a slight decline in chlorophyll a observed between 14 and 15 m below the surface within 300 m downstream of PW3 and PW5 30 days after the 1975 Disposal, there were no significant differences in the phytoplankton variables between the Reference and Disposal Sites.

164. The results from the chlorophyll a, primary productivity, and phytoplankton enumeration studies from the 1976 pre- and post-disposal collections were quite similar to those in 1975 with respect to indicating no statistically significant differences between the Reference and Disposal Sites.

165. The experimental design of the Ashtabula Study did not include sampling for phytoplankton in the water masses in which the disposal plumes were dispersed. In view of the small area that was affected and the short duration of the chemical and physical changes, the overall impact of the Ashtabula dredged materials on the pelagic algae was negligible.

Elutriate-Primary Productivity Bioassays

166. The results of these productivity experiments were calculated in terms of ^{14}C uptake in light and dark bottles. The algae in the bottles were exposed to different concentrations of elutriates from Ponar collected Harbor sediments. These experiments indicated that ^{14}C uptake in the dark bottles generally was stimulated when 10 to 25 mℓ of elutriate was added to the 125-mℓ incubation bottles. However, ^{14}C uptake was suppressed in the light bottles at the same elutriate concentrations. The ^{14}C uptake in the dark bottle was attributed to heterotrophic

activity, possibly by bacteria. This would indicate that the disposal activities may increase the quantity of heterotrophic organisms in the area. It should be noted that many zooplankton graze on bacteria living on detritus particles. Hence, an increase in the bacteria could result in an increase in the zooplankton populations. However, since the bioassay experiment indicated that the heterotrophs are more associated with particulate matter and that the particulate matter from dredging generally settled out of the water column within 12 mins after disposal at Ashtabula, the impact of such heterotrophic activity was not thought to be ecologically significant at the Disposal Sites.

167. The observation that there was less than a statistically significant stimulation of ^{14}C uptake in the light bottles containing elutriates in the ranges of those expected in the Disposal Area also supports the conclusion that the short-term impact of disposal on the phytoplankton was negligible.

Zooplankton

168. The variation in group composition and numbers of the zooplankton observed at Reference Stations PW1 and PW2 over the course of the 1975-76 study is displayed in Figure 10. The zooplankton appeared to be distributed generally in random numbers and taxonomic composition over the study area during this two-year monitoring effort. While higher numbers were observed in the nearshore waters and somewhat lower numbers over the Disposal Areas, no statistically significant change in group composition could be attributed to the disposal of the dredgings.

169. A possible stimulation of zooplankton as a consequence of an increase in the heterotrophic bacteria noted in the above discussion of the bioassay tests was not observed during this study off Ashtabula.

Benthic Macroinvertebrates

170. There were marked differences in the number and composition of benthic macroinvertebrates noted at each collection

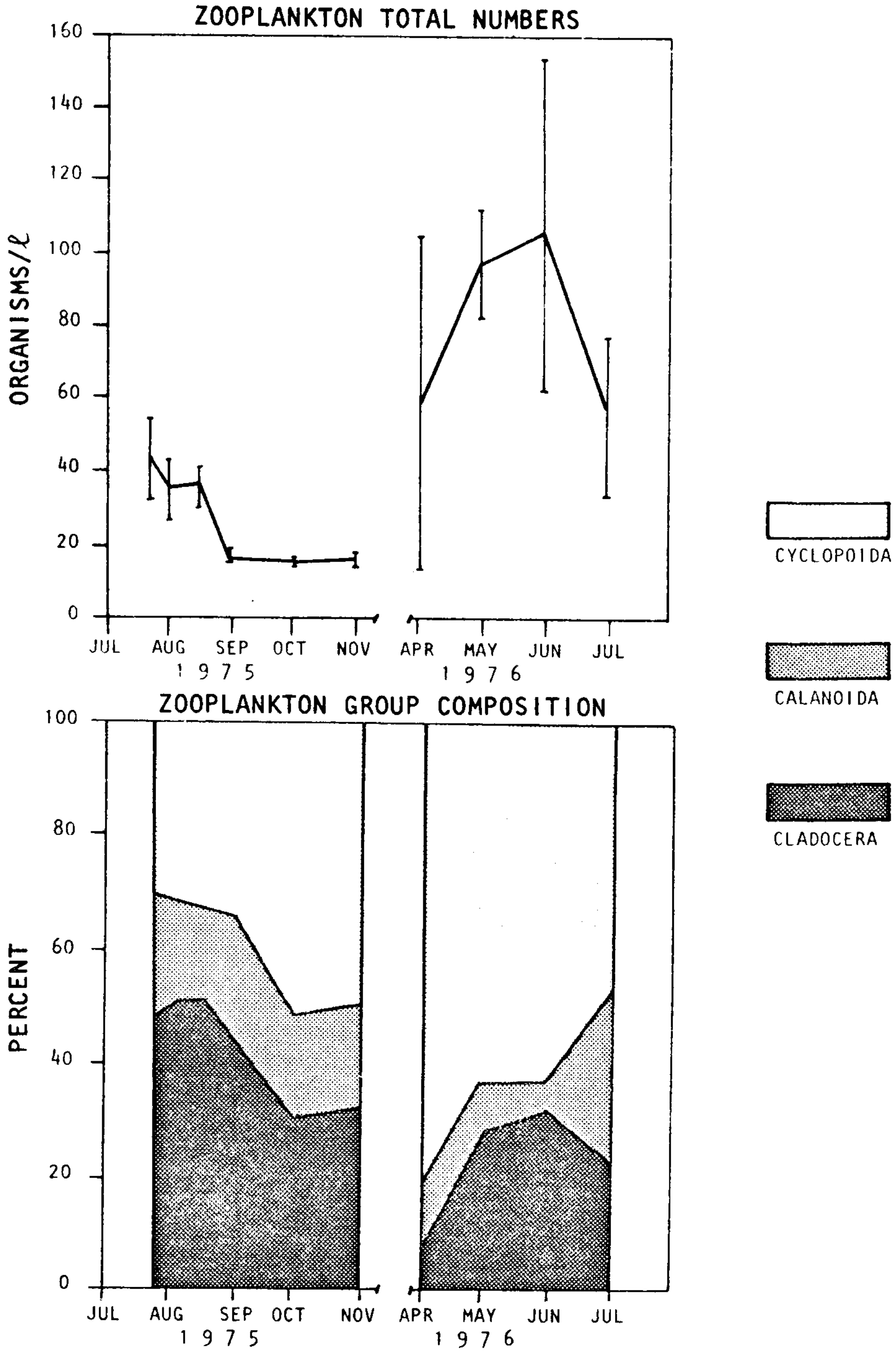


Figure 10. Mean temporal variation in zooplankton total number and group composition for reference sites PW1 and PW2, 30 July 1975 to 8 July 1976. Bars indicate 95 percent confidence intervals for means

station. This is illustrated for the Stations C1 and C3 benthos in Figure 11. These differences were attributed to spacial variations in bottom types at each Collection Site as well as seasonal factors, including the morphological changes of bottom-dwelling larval insects to winged adults. Oligochaetes (sludge worms) remained the most numerically abundant benthic organisms with chironomids (bloodworms) generally found to be in the next order of abundance.

171. The majority of the oligochaetes at the two Reference Sites, C1 and C3, were comprised of immature fauna. The dominant adult species were Aulodrilus pluriseta, Peloscolex multisetosus, Limnodrilus hoffmeisteri, and Aulodrilus americanus. Of these four numerically dominant species, collections from C1 showed higher numbers only for P. multisetosus. Station C3, on the other hand, displayed much higher total numbers throughout the year for the other three major oligochaete species.

172. The Isopoda showed a similar trend at both sites, reaching maximum numbers in midsummer (8 July). This group was represented totally by Asellus sp. (in most cases, Asellus racovitzai racovitzai). The Gastropoda, comprised of Valvata sp. and Amnicola spp., were relatively stable in number throughout the year with changes seen only at the species rather than the order level. Station C3 benthos, unlike those at C1, had an occasional occurrence of the Hirudinea group in the late fall and early spring. As with the chironomids, this group appeared to reach maximum numbers in the winter time.

173. The nematode group was almost totally comprised of Dorylaimus sp. Again, Station C3 supported much higher numbers than C1. In general, it appeared that because of the domination of the sphaerid group at the C1 Reference Site, many of the other species and groups were suppressed in relative numbers although not in diversity as indicated by similar trends in species number between C1 and C3. These biological differences were believed to be related to the variations in bottom substrates

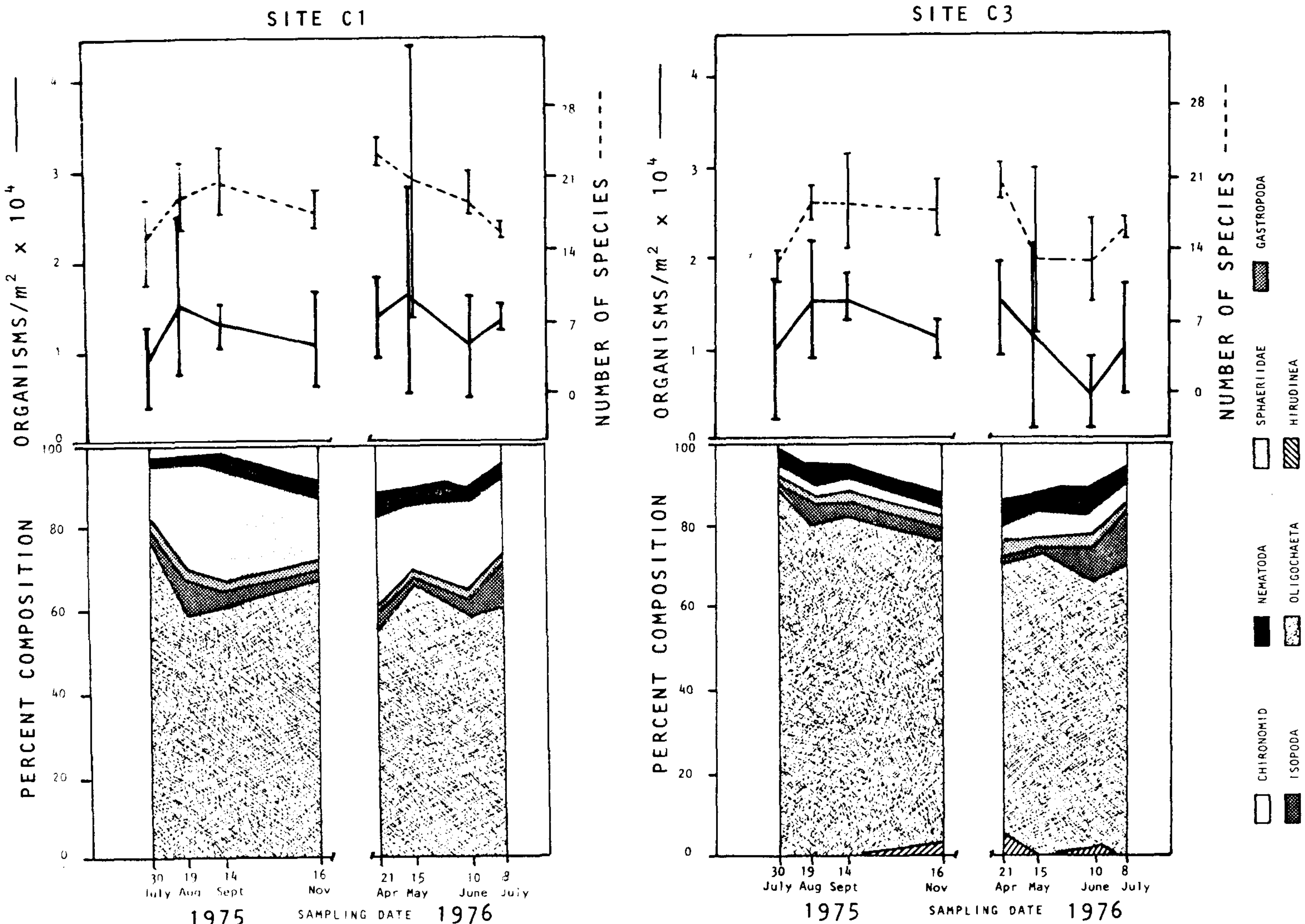


Figure 11. Total mean number of organisms, species number and group composition of benthic macroinvertebrates at reference sites C1 and C3 over the duration of the disposal study. Bars represent 95 percent confidence intervals

between the two areas.

174. Vertical distribution of the different major groups over the duration of this study showed some interesting trends (Figure 12). The majority of organisms were found in the first 5 cm of the sediment (Section No. 1) which included the more mobile forms, the chironomids and the isopods. The oligochaetes were relatively evenly distributed throughout the sediment with no section ever showing much less than 50% composition. As found in many marine situations (Smith and Howard 1972, Oliver 1973), the larger organisms (comprising more biomass) were found deeper in the sediments. These included the molluscs (sphaerids and gastropods) that exhibited a mean dry weight of 2.12 mg per individual based upon analyses of more than 650 organisms. In contrast, the oligochaetes weighed a mean of 0.20 mg per individual for dry weight measures of over 6,000 individuals. These molluscs showed relative maximum densities in the second and third sections (> 5 cm deep) of the sediment. The lowest numbers of organisms per square meter were observed in the second (5-20 cm) and third (> 20 cm) sections during the early to mid-summer periods. The only occurrence of ostracods within the macrobenthos was observed in the third section in late spring (15 May). When the isopods reached peak numbers (10 June - 18 July), they distributed themselves throughout the sediment, perhaps as a result of competition.

175. The first 30 days after the disposal period appeared to be the most critical for the benthic communities that had been disposed upon during the operation. This was a major consideration regarding the 1976 experimental design which was to intensively study the dynamics of impacted communities. What occurred in the first 30 days played a major role in the events taking place later in the study on the Disposal Sites. The general trends observed for the Disposal Sites included relatively no change in species number at most locations over the first 30 days. The total number of organisms, however,

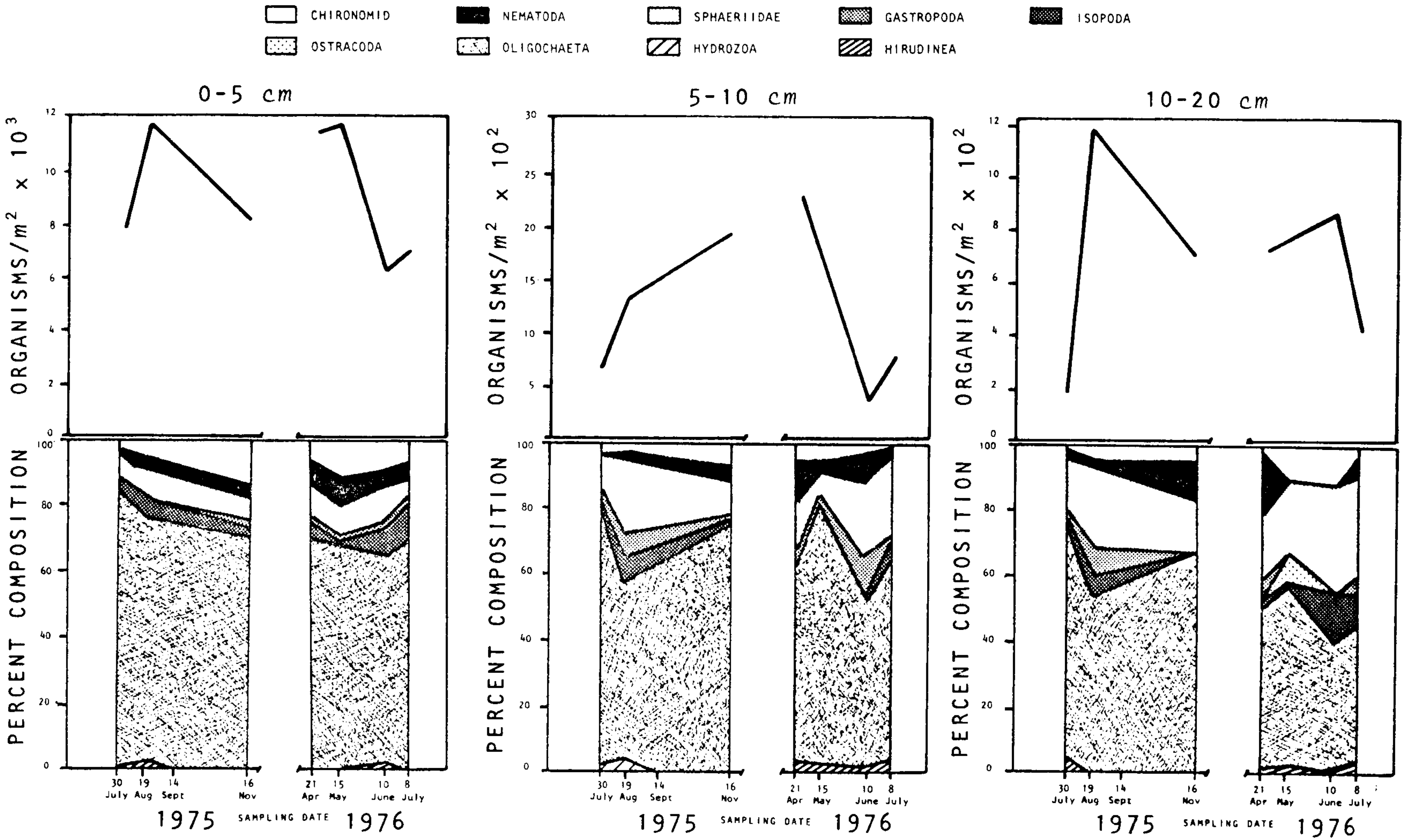


Figure 12. Vertical distribution for total mean number of organisms and group composition of benthic macroinvertebrates over the disposal study duration at site C3

increased immensely (Figures 13 and 14). The fact that many faunal groups had disappeared from the Disposal Sites during this interval, coupled with the observations of no real species number changes and large organismal number increases, indicated that new species had replaced the eliminated ones. Also, these newly introduced fauna were able to temporarily increase in numbers within the changed environmental conditions at the Disposal Sites. The faunal changes, including the resulting distribution pattern with time, were characteristic of a variable community (Pielou 1975). Examples of this instability were the large increases observed for total numbers associated with the high standard deviations (Figure 14), especially at SD7 and SD11 in 1976. Replicate samples obtained from the same immediate areas were very different, suggesting extreme patchiness or high variability in populations and general instability.

176. Analysis of vertical distribution of fauna within the sediment is very important in relation to bioturbation and the availability of benthic fauna to other trophic groups (Kajak 1971). In many instances the maximum biomass can be found in deeper sediment layers (Coleman and Hynes 1970) and is comprised primarily of larger organisms. This phenomenon was observed in the present study at the Reference Sites (Figure 12). The trend after disposal did not show this to be the case, however, for the Disposal Sites. The collections of vertical sections 5 days after disposal (Figure 15) indicated that any larger organisms present (e.g. chironomids and isopods) were found only in the surface layers, and by 30 days after disposal (Figure 16), they had disappeared from all stations. Since these fauna did not vertically distribute themselves, they were subject to both predation and physical forces, which added to the instability of the communities observed on the Disposal Sites. A possible cause for these organisms not moving into the sediment was related to the environmental conditions of the deeper layers. Low oxygen concentrations, low interstitial

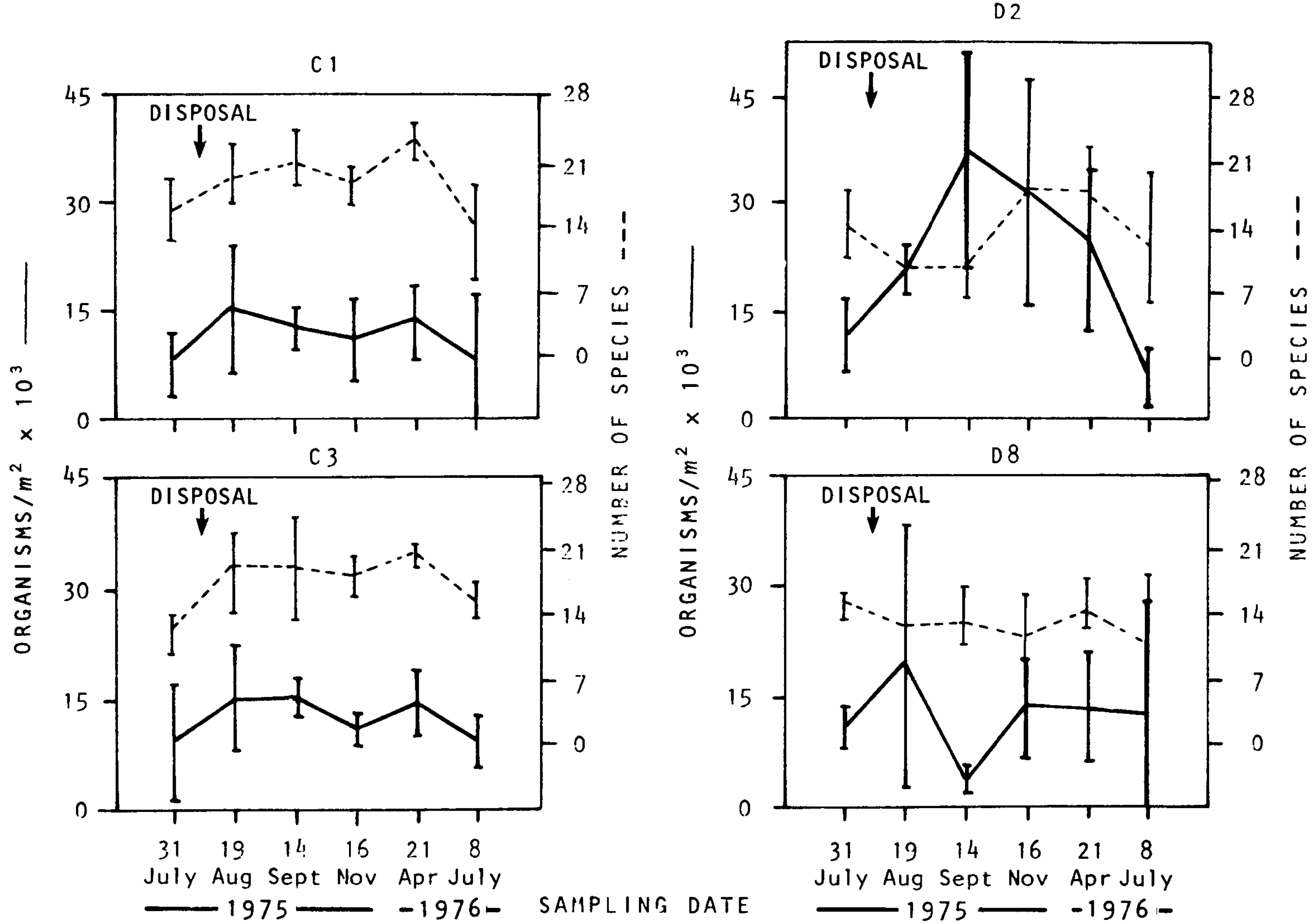


Figure 13. Mean number of species and organisms for the total macrobenthic invertebrate fauna of reference sites C1 and C3 and center disposal sites D2 and D8 over the 1975 disposal study duration. Disposal occurred 4-14 August 1975. Bars represent 95 percent confidence intervals

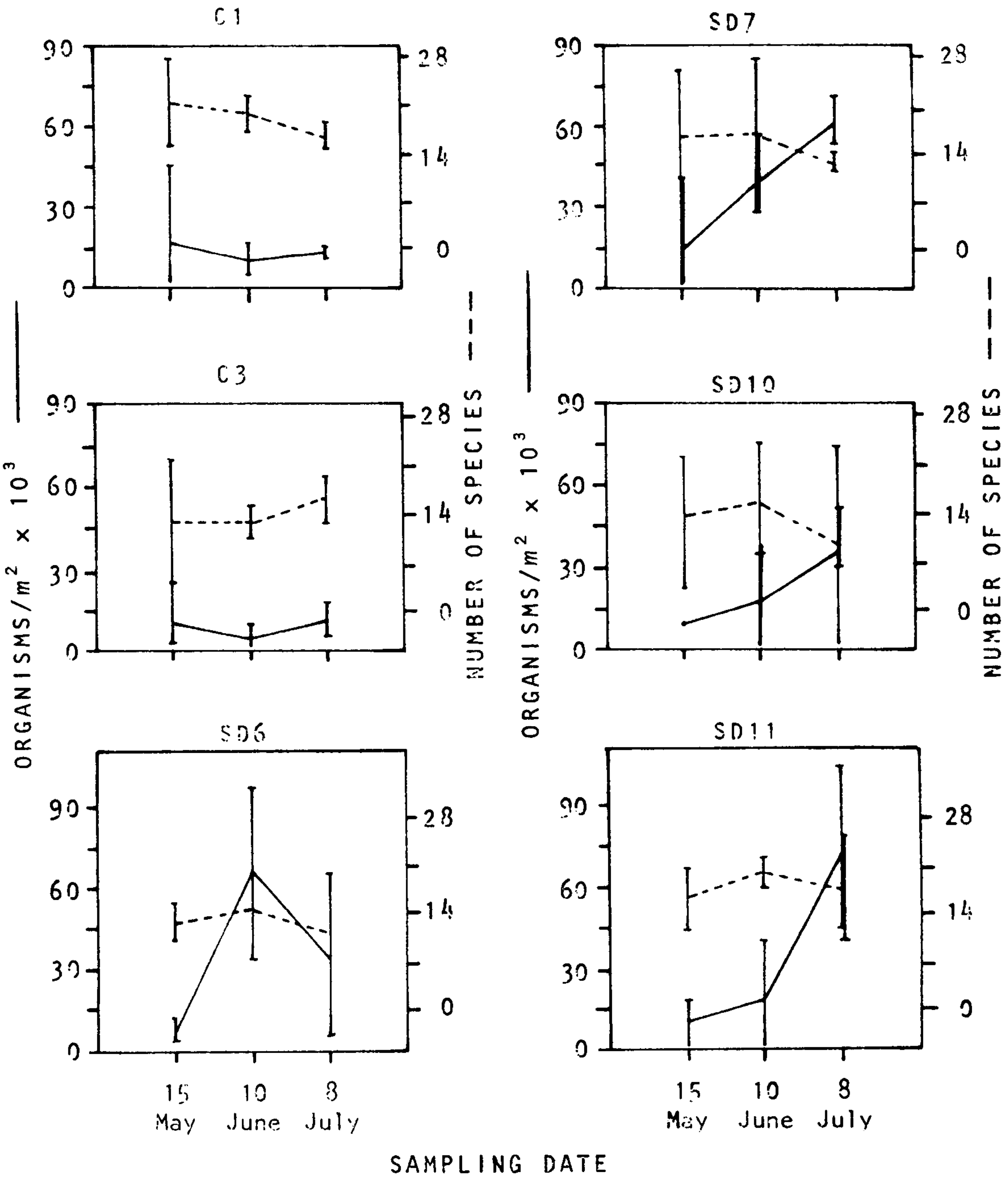


Figure 14. Mean number of species and organisms for the total macrobenthic invertebrate fauna of the reference sites C1 and C3 and center disposal sites SD6, SD7, SD10, and SD11 over the 1976 disposal study. Disposal occurred 24-26 May 1976. Bars represent 95 percent confidence intervals

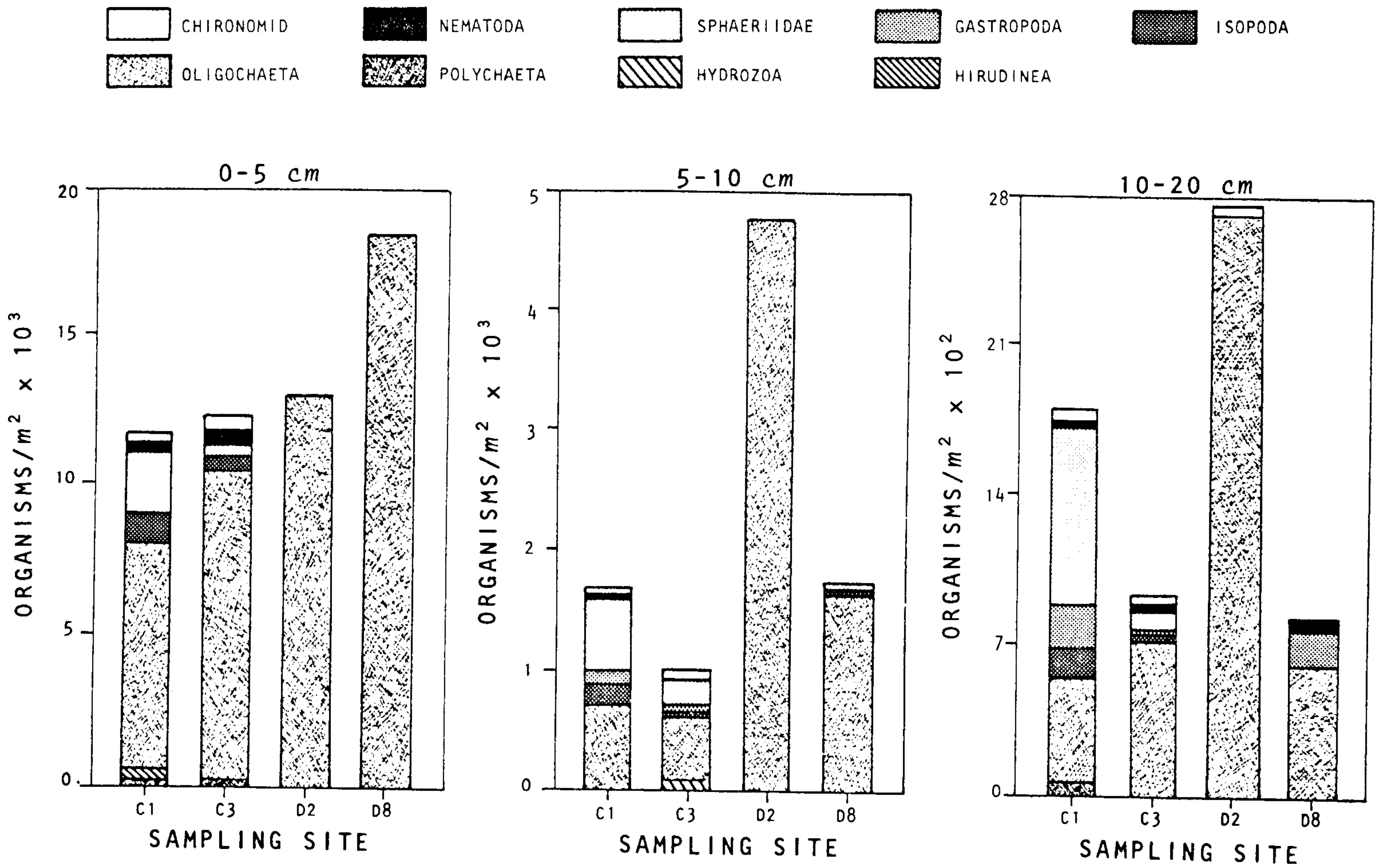


Figure 15. Comparison of vertical distribution of benthic macroinvertebrate mean total numbers and group composition for reference sites C1 and C3 and center disposal sites D2 and D8 sampled 5 days after disposal, 19 August 1975

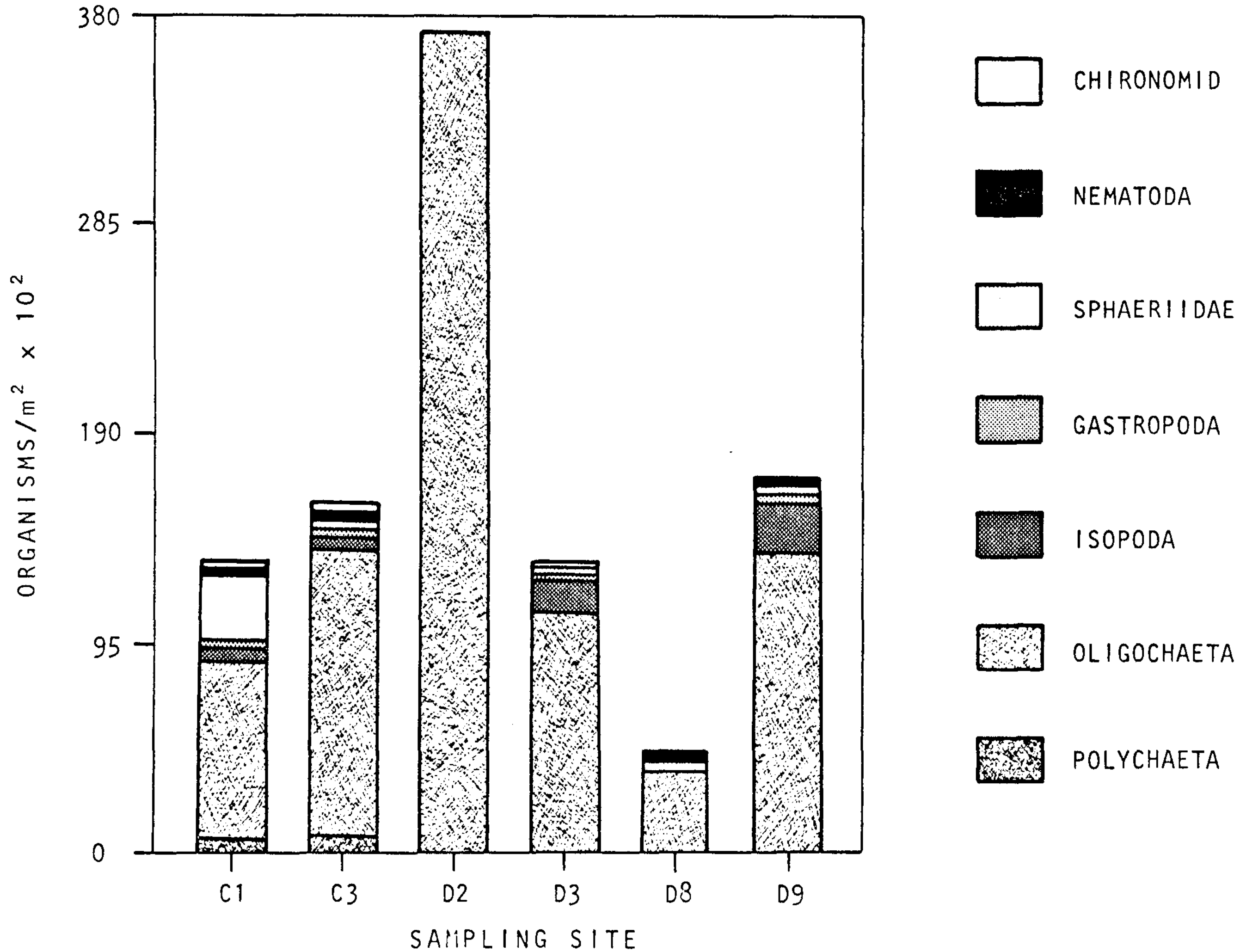


Figure 16. Comparison of benthic macroinvertebrate mean total numbers and group composition for reference sites C1 and C3 and disposal sites D2, D3, D8 and D9 sampled 30 days after disposal, 14 September 1975

water content, increased compaction, and highly reducing conditions can result from the burial of natural lake bottom sediments (Oliver and Slattery 1976). Consequently, it was assumed that these organisms would not survive in the deeper sediment layers; therefore, they either migrated to another more favorable location or were eliminated by the above physical and/or biological pressures. However, such disappearance and increased instability were not evident during this experiment (Figures 13 and 14).

177. The results from the discriminant analysis provided valuable information concerning the disposal event and its impact on both the immediate benthic habitat as well as the habitats in the general area. The 1975 disposal operation of Harbor dredgings impacted an area covered by most sampling sites, as indicated by faunal community compositions 5 days after disposal at these sites. Three of the five sites supported communities similar to the Center Disposal Site (D2). The results of the River dredging disposals (on D8) indicated that only Station D8 was impacted initially. The two outlying downcurrent sites (D6 and D12) were not initially affected by disposal. In 1976, according to similarities in communities, the impact of disposal was noted on Quadrats SD1, SD3, and SD15 besides the Center Disposal Sites, an affected area slightly larger than the area affected during 1975. The remaining quadrats sampled (six) showed no change in community structure. Consequently, it appeared that the initial disposal impact was confined to a relatively small area and was more a function of the actual path of the hopper dredge during disposal. The results 30 days after disposal, however, did not show the same pattern. Several sites from the 1975 disposal event supported communities comparable to those at the Center Disposal Sites 30 days after disposal. These similarities were not observed 5 days after disposal. Three additional locations (D3, D7, and D9) supported communities similar neither to those

at the Center Disposal Sites nor the References. These stations exhibited much higher numbers of mobile faunal groups, such as the isopods, than the Reference locations. Therefore, it was assumed that many of the fauna that disappeared from the Center Disposal Sites as described previously were probably migrating to areas of higher predictability (Slobodkin and Sanders 1969) that were much less affected than the Center Sites.

178. The same phenomenon was not noted during the 1976 operation 30 days after disposal. By the 30-day sampling event all quadrats except for the four Center Sites displayed conditions similar to those at the Reference Sites (Figure 17). These differences in faunal movements were explained in part by the differences in distance between quadrats compared to the distance between sampling stations for 1975. The quadrat distances (1976) were much greater, and the migration of species away from the Center Sites did not cover these greater distances. Movement of the more mobile and less tolerant species from the low predictability areas (Center Disposal Sites) to the more stable higher predictability areas of the bottom habitat appeared to be one of the consequences of the disposal impact on the benthic environment. As Sanders (1969) stated, invasions of more stable areas are likely to be in response to perturbations in the environment's immediate past, resulting in underexploitation of resources or space. This appeared to be the situation in the nearshore waters of Ashtabula if one considers the past history of disposal in this area.

179. The continuation of sampling for 1975 indicated that even 90 days after disposal, the areas quite distant from the Center Sites, D6 and D12, supported communities that showed similarities to those of the Center Sites. Since these areas were not initially affected by disposal, it was assumed that with time the impact of disposal spread as less tolerable species initially invaded other environments. Later, even the populations thriving on the Center Disposal Sites (e.g.

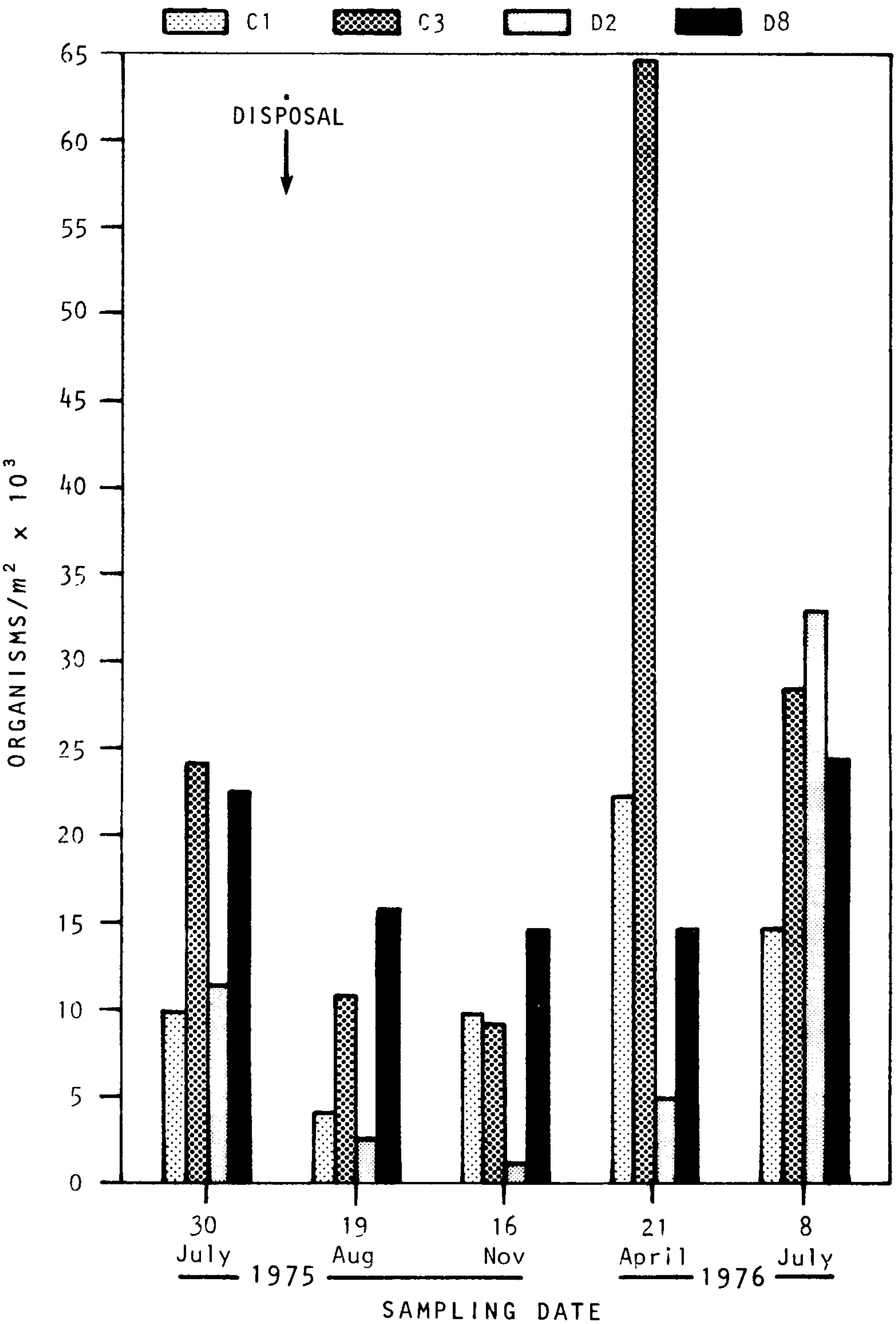


Figure 17. Mean total number of harpacticoids at reference sites C1 and C3 and center disposal sites D2 and D8 over the 1975 disposal study. Disposal occurred 4-14 August 1975

Limnodrilus hoffmeisteri, Peloscolex multisetosus, and Potamothrix vejdovskyi) expanded their range due to competition pressures from increased numbers.

180. The fact that perturbations on the benthic environment have been shown to result in the underexploitations of resources and space (Sanders 1969) perhaps explains in part the observed appearance of amphipods in the samples taken from D2 almost a year after disposal. However, they did not appear in the Reference Site samples. The amphipods were able to occupy some available space and/or utilize some available resources (i.e. food) at the Disposal Sites, which perhaps were indirectly related to disposal of the previous year.

181. The 1975 disposal operation was especially informative because dredged material from two different sources was disposed of on the Experimental Sites (River dredgings on D8 and Harbor dredgings on D2). The results observed suggested that the two Center Disposal Sites differed from the Reference Area because of the disappearance of the isopods, chironomids, etc., and the increase in oligochaetes, especially L. hoffmeisteri, which were abundant in both the River and Harbor and are indicators of more polluted conditions (Brinkhurst 1967). The two Disposal Sites, however, also differed from one another due to the difference in oligochaete species observed and the total number of organisms supported. Station D8 collections displayed a much greater abundance of Aulodrilus spp. after disposal, especially A. americanus, than did Station D2. The D2 collections showed much higher numbers and more species of Limnodrilus spp. than D8. Site D2 samples also exhibited much higher total numbers of all organisms, which indicated that many of these had been imported for the Harbor habitat, an area that also exhibited much higher total numbers of organisms than the River. The preceding suggests that it is very important to consider the communities and physicochemical conditions of the material to be dredged in respect to the properties of the habitat receiving

the dredged material during disposal. Obviously from the results presented, it was apparent that the two Disposal Site communities responded in completely different ways following disposal and continued to show differences throughout the study, even with respect to recovery of these communities.

182. One of the important observations derived from this project was the fact that, in many cases, actual effects of the disposal event on the benthic fauna were not evident until the dynamics of individual species were closely examined. There were a number of gross changes that occurred, such as increases in total number of organisms, increases in percentage of oligochaetes in the total community composition, and decreases in many of the other common groups (e.g. nematodes, chironomids, and isopods). As indicated previously, the fact that no gross changes were observed in total species with time possibly was misleading. The observation that many species were eliminated and replaced by others previously not noted in the area was not readily apparent from the presentation of species number for each site over time (Figures 13 and 14). Therefore, examination of several of the species within the major faunal groups observed during this project was an essential part of the evaluation process concerning a comprehensive treatment of the impacts of open-lake dredged material disposal on the benthic fauna.

183. The Oligochaeta have been identified as a possible indicator of polluted environments (Goodnight and Whitley 1960). This indicator also appeared in the situation from the Ashtabula study. The oligochaetes represented more than 95% of the community in most of the Ashtabula River and Harbor samples taken both in 1975 and 1976. The percentage of this group was always large at the Disposal Sites, especially for the 5- to 90-day sampling periods (greater than 98%). Goodnight and Whitley (1960) suggested that a population of 80% or more of oligochaetes in the total benthic macroinvertebrate community indicated a high degree of either organic enrichment or industrial pollution. They

also suggested that oligochaete compositions between 60 and 80% indicated questionable pollution conditions. Most of the Reference Site communities were characterized by oligochaete compositions in the latter classification group. Therefore, one of the obvious effects of disposal was the increase in oligochaete dominance observed on the Disposal Sites. Evaluation of some of the generic components comprising this dominant group revealed patterns that could be related directly to the process of deposition. The ratio of Limnodrilus spp. to Aulodrilus spp. was changed markedly after disposal occurred. Most Disposal Site oligochaete groups were composed primarily of Limnodrilus spp. with L. hoffmeisteri being the numerically dominant taxon, while the Reference Site oligochaete groups consisted largely of Aulodrilus pluriseta. Brinkhurst (1967) suggested that the percentage occurrence of L. hoffmeisteri in relation to other oligochaetes may prove to be a useful indicator of organic pollution. This was observed for the River samples, and, to a lesser extent, the Harbor samples. Similar conditions appeared to be created by the disposal process in the open Lake since L. hoffmeisteri not only increased but also maintained extremely high numbers throughout the study duration at the Disposal Sites.

184. A number of the species encountered after the disposal event were not seen prior to deposition in the Lake environment. These included L. udekemianus, L. claparedianus, L. cervix, and L. maumeensis. T. tubifex, although observed in the Lake habitat at various times within the collections from the Reference Sites, never exhibited great abundances similar to those observed in the Disposal Site samples after disposal. The species mentioned above were all recorded in large numbers in the River and Harbor samples, suggesting that these may have been imported to the Lake habitat during the disposal operation. The fact that they were able to survive, increase in number (in many cases), and even invade other immediate areas suggested that the environment had been altered by disposal and had become conducive to

the production of foreign species associated with more polluted habitats. The presence of several such species, including L. udekemianus, was observed even the following summer, almost a year after the 1975 disposal event. The majority of the rest of the oligochaete species examined individually increased in numbers at the Disposal Sites compared to the References. This probably was due to increased organic matter accumulation (Goodnight and Whitley 1960) plus expanded community space and resources left available with the disappearance of several of the less tolerant species (Sanders 1969). One oligochaete species, A. limnobius, disappeared from some Disposal Site collections and decreased in numbers in others after the deposition operation. This pattern was similar to that discussed previously for the ratio of Limnodrilus to Aulodrilus observed in the Disposal Site samples compared to those from the Reference Site samples.

185. Other species (in addition to those belonging to the Oligochaeta) showed adverse responses to disposal. The chironomids, Chironomus sp. and Procladius sp., disappeared 5 days after disposal at the Disposal Sites in 1975. Chironomus sp. never returned to reference-level numbers over the entire study duration. Procladius sp. appeared to recover on the Disposal Sites 90 days after disposal but then was almost totally eliminated the following spring at D8. This may have been related to natural processes in the Lake, causing a release of some toxicant on this Disposal Site or else an effect on the organism's annual life cycle that inhibited a recovery from the disposal perturbation over the study duration. The gastropods, Valvata spp., also exhibited adverse effects from disposal as indicated by their complete disappearance at two of the three disposal sites 30 days after dredged material disposal. The isopod, Asellus sp., as discussed previously, also was severely inhibited from populating the Disposal Sites after disposal.

186. An interesting contrast was observed between the data concerning the Isopoda and Ostracoda, both members of the class

Crustacea. As already indicated, Asellus was severely impacted. The ostracods, on the other hand, exhibited large increases immediately after the disposal event. The fact that the numbers at the Disposal Sites were similar to the References 90 days after disposal suggested that two different species may have been causing the trends observed. Ostracods were observed in the River sediments. There was a strong possibility that these species were transported in the dredged material to the Lake habitat, in a manner similar to many of the oligochaetes. Consequently, when disposal occurred, these River species replaced the Lake species and were able to thrive. Cole (1953) indicated that some species of ostracods choose softer sediments than others because of their burrowing habits. In addition, this group has been cited for their ability to withstand severely stagnated conditions (Moore 1939) that may have occurred in the deeper sediment layers. With time as well as erosion and/or compaction of the sediments (Oliver and Slattery 1976), the imported species appeared to be replaced by the Lake species migrating from other areas.

187. Another crustacean member, the harpacticoids, displayed an adverse response to disposal similar to that exhibited by the isopods. This effect was believed to be related to the life cycle of the animal because of the reaction of encysted stages that were the dominant forms of this organism during the period of disposal. Very few cysts were observed in the Disposal Sites compared to the References after disposal. The apparent disappearance of these forms, a major part of the organism's life cycle (Dineen 1953), did not have a major effect upon the populations observed throughout the remainder of the long-term study (Figure 17). While numbers remained low at the Disposal Sites, there was a return to predisposal levels which was observed almost a year after disposal.

188. Several of the other benthic groups such as the chironomids, isopods, sphaerids, and harpacticoids displayed trends at many of the Disposal Sites that could only be related

to some deviation from their life cycles following disposal. For example, two chironomids, Chironomus sp. and Procladius sp., observed in this area, based on their abundance patterns at the Reference Sites, probably emerged during July and August. This was similar to cycles reported elsewhere (Hilsenhoff 1966). Although occurring again at the Reference Sites in the fall after disposal, they were not present in the Disposal Site collections in similar numbers until more than 90 days after disposal. The benthic environment was still altered markedly as long as 30 days after disposal (14 September 1975). This was the period when chironomid oviposition probably occurred in this area (Hilsenhoff 1966). The larvae possibly did not inhabit the Disposal Sites and, consequently, any numbers observed later in the investigation probably were the result of migration from other areas. Thus, the populations were lower and may have directly affected the rest of the community, especially predators.

189. The following spring, when chironomid populations appeared to reach their maximum at the Reference Sites, the Disposal Site samples still showed much lower numbers, except for Procladius at D2. Either fewer numbers of these species were present at the Disposal Sites throughout the study or else something occurred in the physicochemical environment between the 16 November and 21 April samplings. Whichever factor was involved, the result was a decrease in either total number or in the frequency of larger organisms that would be retained on the sieve mesh. Whatever the circumstance, the life cycle of this group was altered. This was an example of how the dredged material disposal possibly can impact the benthic community when disposal occurred during an important phase (i.e. reproduction) of a particular faunal life cycle.

190. As discussed above, the encystment phase of the harpacticoid's life cycle also appeared to be interrupted by disposal in 1975. Consequently, the patterns observed for this group possibly were different at the Disposal Sites than observed

at the Reference Sites. Normally, these organisms encyst after fall overturn and reproduce during the winter and early spring (Moore 1939, Dineen 1953). Possibly because of the interruption of encystment by disposal perturbations, the whole cycle appeared to be affected at the Disposal Sites and, thus, numbers remained low compared to the Reference until the following summer, 8 July 1976 (Figure 17). The initial interference in the life cycle may have caused a lag in this species' abundance patterns. However, the latter was corrected by the following year.

191. In many instances, similar patterns as those described for the chironomids and harpacticoids also were evident for the sphaerids and isopods. Since the breeding period for many of these benthic forms occurs throughout much of the year (Baker 1928, Pennak 1953, Hilsenhoff 1966), the disposal operation may account for many of the impacts observed for specific organisms during this investigation.

192. Since the interruption of normal faunal life cycles appeared to be one of the more important biological results noted during this investigation, it is suggested that a need exists for future experimental studies to determine the actual (rather than implied) life history, changes, and interactions that result from disposal of dredged material in the open-water lacustrine environment. If these studies had been conducted during this investigation, the ecological relationships between community members, including recolonization after disposal, could have been more explicitly identified.

Fisheries

193. The species of fish observed in the Ashtabula area of Lake Erie over the course of the 1975-76 survey are shown in Tables 5 and 6. Nearshore areas were classified as those having a depth < 7.62 m (25 ft.). Many species observed in the study area were not normally present in the Disposal Areas. Those species present in the Experimental Areas were also present, sometimes in greater numbers, in areas of shallower

TABLE 5

Nearshore and Offshore Fish Species 1976-1977

Species	Common Name	Nearshore	Offshore
Alosa pseudoharengus	Alewife	x	x
Dorosoma cepedianum	E. Gizzardshad	x	x
Osmerus mordax	Rainbow Smelt	x	x
Lota lota	E. Burbot	x	x
Lepisosteus osseus	Longnose Gar	x	
Oncorhynchus kisutch	Coho Salmon	x	x
Esox lucius	Northern Pike	x	
Catostomus commersoni	White Sucker	x	x
Moxostoma duquesnei	Black Redhorse	x	
Moxostoma erythrurum	Golden Redhorse	x	
Moxostoma macrolepidotum	Northern Redhorse	x	
Carpiodes cyprinus	Quillback	x	
Cyprinus carpio	Carp	x	x
Carassius auratus	Goldfish	x	
	Carp x Goldfish	x	
Notemigonus crysoleucas	Goldenshiner	x	
Notropis atherinoides	Emerald Shiner	x	x
Notropis hudsonius	Spottail Shiner	x	x
Notropis spilopterus	Spotfin Shiner	x	
Notropis stramineus	Sand Shiner	x	
Rhinichthys cataractae	Longnose Dace	x	
Pimephales notatus	Bluntnose Minnow	x	
Noturus flavus	Stonecat Madtom	x	x
Ictalurus punctatus	Channel Catfish	x	x
Ictalurus melas	Black Bullhead	x	
Ictalurus natalis	Yellow Bullhead	x	
Ictalurus nebulosus	Brown Bullhead	x	
Morone chrysops	White Bass	x	x
Fundulus diaphanus	E. Banded Killifish	x	
Percopsis omiscomaycus	Trout-perch	x	x
Pomoxis annularis	White Crappie	x	
Pomoxis nigromaculatus	Black Crappie	x	
Ambloplites rupestris	N. Rockbass	x	x
Micropterus dolomieui	Smallmouth Blackbass	x	x
Micropterus salmoides	Largemouth Blackbass	x	
Lepomis cyanellus	Green Sunfish	x	
Lepomis macrochirus	Bluegill Sunfish	x	
Lepomis gibbosus	Pumpkinseed Sunfish	x	
Stizostedion canadense	Sauger		x
Stizostedion vitreum	Walleye	x	x
Perca flavescens	Yellow Perch	x	x
Percina caprodes	Logperch Darter	x	
Etheostoma nigrum	Scaley Johnny Darter	x	
Aplodinotus grunniens	Freshwater Drum	x	x
Cottus bairdi	Northern Mottled Sculpin	x	x
	T O T A L S	44 species	20 species

TABLE 6

Species Composition and Abundance
at Five Ashtabula Area Study Sites.
Gill Nets Only.

*Collected by trawls; not figured in gill net abundances.

Common Name	F-7	F-8	F-17	F-18	F-28
Alewife	0.31	4.62	9.53	3.07	6.26
Gizzardshad	0.31	7.17	9.14	3.75	5.01
Coho Salmon	-	-	-	0.11	-
Rainbow Smelt	1.24	2.57	1.31	5.29	0.53
Northern Pike	-	-	-	-	0.07
Carp	0.21	0.61	1.30	0.23	2.50
Goldfish	-	-	-	-	0.20
Emerald Shiner	*	*	*	*	*
Spottail Shiner	-	0.21	0.13	0.06	0.13
Quillback	-	-	-	-	0.46
Black Redhorse	-	-	-	-	0.07
Golden Redhorse	-	-	-	-	0.33
Northern Redhorse	-	-	-	-	0.13
White Sucker	1.14	0.72	2.22	0.40	6.46
Channel Catfish	-	-	0.13	-	0.26
Stonecat Madtom	-	0.51	0.26	0.17	4.28
Burbot	0.21	0.41	0.28	-	-
Trout-perch	0.83	1.54	1.44	1.14	0.53
White Bass	-	0.21	0.26	0.46	2.11
White Crappie	-	-	-	-	*
Black Crappie	-	-	-	-	*
Rockbass	0.10	0.10	-	-	1.25
Smallmouth Blackbass	-	-	-	0.06	0.13
Bluegill Sunfish	-	-	-	-	*
Sauger	-	0.21	0.65	-	0.07
Walleye	-	0.72	0.39	0.11	1.71
Yellow Perch	91.73	74.31	66.58	78.90	62.85
Logperch Darter	-	-	-	-	*
Scaley Johnny Darter	-	-	-	-	*
Freshwater Drum	3.93	5.55	6.66	5.97	4.74
N. Mottled Sculpin	-	-	-	-	*

waters. Although community structure was different, these results were consistent with the results of similar studies near Cleveland, Ohio (White et al. 1975).

194. During the summer predisposal studies, a steady decline in the total fish abundance was documented in the experimental area. These populations (primarily the dominant species, yellow perch) continued to decline steadily until early August when the lowest level was recorded. During the 1 August - 14 August period it was not uncommon to catch no yellow perch in a 600-ft. gill net set for 18 to 24 hrs. Fathometer tracings made during this predisposal monitoring period supported the conclusions that there was a lack of yellow perch in the study area.

195. Mid-water species also demonstrated slight declines during the late summer, although smelt, alewife, and gizzardshad were present in small numbers. Large schools of small fishes, mainly young-of-the year smelt, were present at depths of 15 to 40 ft. These results were not entirely unexpected since trends identical to these have been observed in Cleveland waters and elsewhere (White et al. 1975; White 1974).

196. Fish populations began to increase in September and reached a peak in November when sampling was discontinued due to weather conditions and shore ice formation. Studies by Caroots (1976) indicate that this increase continues throughout the winter, principally due to increases in adult gizzardshad. Smelt also increase during the winter period (White 1974). Yellow perch near Cleveland demonstrate offshore declines during January and February with subsequent increases to the highest level of the year in April-early May. Such an annual abundance cycle is probably true also of the Asthabula area.

197. Samples were first taken in 1976 in March, shortly after the disappearance of Lake ice. These samples indicated that offshore populations of perch, smelt, trout-perch, and gizzardshad were all very low. Offshore populations of yellow perch increased steadily through April and May, while dramatic

increases were observed nearshore in May. Spawning occurred in May and extended into the early portion of June. Nearshore and offshore populations of nearly all species, including yellow perch, remained relatively constant through the May-June period. In July the decline in yellow perch numbers that occurred in nearshore areas was as striking as the May increase. However, increases continued in offshore areas which probably was the result of offshore movement of nearshore fish. Species other than yellow perch maintained their high numbers throughout the May-September period.

198. By late August of 1976, as in 1975, offshore yellow perch populations had declined to very low levels. It was not uncommon during this period to capture no fish of any species in a 24- to 36-hr gill net collecting period. Nearshore yellow perch populations had again begun to increase, as was the case in 1975. The fluctuation of the yellow perch population that occurs in the offshore study area was shown to consist of two peaks - one in the June-July period and a lesser one in late September-October. The lowest numbers of yellow perch were recorded as no perch per 24 hrs per 1000 ft. of gill net. This was documented on 5-9 August 1975 and 20-28 August 1976.

199. Other species in offshore areas also decline in numbers as summer progresses. Smelt reach a peak abundance in mid-May when spawning mortality drastically reduces the population of adults. Yearlings of smelt, however, are abundant at mid-water depths throughout much of the summer. Alewife, young gizzard-shad and trout-perch exhibited declines in offshore areas similar to those demonstrated by the yellow perch. By August these species had become extremely rare in offshore areas.

200. Throughout the study period, the yellow perch was clearly the dominant species present in the bottom waters of offshore areas. Most collections contained 80 to 100% yellow perch, and rarely was a collection made where yellow perch comprised $< 60\%$ of the total catch. Perch abundances thus became the overriding factor in community structure. In fact, during some periods

perch comprised the entire community of larger demersal nektonic forms. Species diversity was poor in the bottom waters of all offshore areas, again due to the influence of the yellow perch population. Shannon-Weaver diversity indices normally ranged from 1.10 to 0.01 or less. To utilize community structure in this instance would have been a valuable tool for predicting impact only if large numbers of additional species or numbers of a few species had colonized the Disposal Area. Since this did not occur, and since yellow perch populations remained similar at all sites, the impact of disposal must be considered to have been negligible. The fact that such change was not observed may have been due to a lack of species available for colonization, however, and disposal in areas where a diverse community structure is present might result in different impacts.

201. The effects of disposal on pelagic fish species appear to be minimal. Adults and young of these species were unaffected by the disposal events. They were found to enter plume material with regularity and were collected in similar numbers at all offshore stations during each sample period.

202. The floating eggs of the emerald shiner and pelagic fish larvae appeared to be unaffected as well. However, since elutriate studies were not conducted, it is not possible to discuss effects of plume materials on these young stages. A potential impact such as that described in elutriate studies on phytoplankton could occur with these larvae.

203. Bottom-dwelling fish species responded negatively to the actual disposal event by migrating from the immediate area of disturbance. The area was quickly repopulated, usually within 15 to 30 min., and within 1 hr after disposal the fish populations appeared similar to all other offshore locations. It is probable that this rapid repopulation of the Disposal Area was due to the general random movement of the fish fauna, especially since no attraction or concentration of fish at the Disposal Site was noted. Since fish are present at the Disposal Site so soon after disposal, it is also possible that toxic materials leached from the sediment could

be accumulated by this segment of the fish population.

204. Studies on the species composition of all sites in offshore areas indicated that during the course of the entire study all sites were similar. No significant changes could be ascertained either in diversity or abundance of individual species. It was felt that movement past the disposal piles or in the general area was not inhibitive to the local fish fauna. Probably no disruptions in general migratory patterns would occur as a result of disposal material.

205. Because of the importance of isopods and chironomids in the diet of the yellow perch, the impact of disposal on these organisms becomes more critical. While documentation of a reduction of chironomids and an elimination of isopods was established in the benthic study, suggestions were also made that these organisms migrated from the area rather than having been buried and killed. If the Disposal Area was very small, the normal foraging behavior of the yellow perch would enable it to find isopod sources in nearby areas, but if disposal occurred over larger areas (with the same effect) a food source might become seriously depleted.

206. Within 90 days chironomid populations were reestablished in Disposal Areas and these could have served as an alternate food source for yellow perch. However, during the post-emergence period for chironomids in late July and August, these are naturally unavailable. Snails, which are not normally a principal food item, could be utilized but results indicate that these were affected in the same manner as the isopods. With disposal of similar quantities of material over a larger area, yellow perch would be forced to turn to an alternate source of food, namely other fish species.

207. Studies of seasonal feeding behavior suggest that yellow perch shift food items based on availability. Food intake is dominated by isopods in spring with an increasing amount of chironomids through mid-May. During chironomid emergences in July, the isopods and snails become less important and chironomid pupae formed the bulk of the diet. Fish and snails became more important in offshore feeding areas after July. Fish and chironomids

became increasingly important as winter approached.

208. Considering the above impacts on the major food organisms utilized by fish, the widespread disposal of dredged materials in Lake Erie near Ashtabula in the late summer or fall would have little effect on fish feeding behavior. Chironomids, the major spring-summer food source, if impacted during one year would be recolonized by the following year. Small fish, which exhibited little response to disposal, would be available as a food source in the spring-summer period.

209. Disposal of dredged material in the late spring could adversely impact the game and commercially valuable species, particularly yellow perch, in the waters off Ashtabula. During this period the fry or young-of-the-year fish are unavailable and the perch are feeding largely on benthic macroinvertebrates. Disposal of dredged material would force the populations of benthic-feeding species to move temporarily to other areas, which could be termed a secondary avoidance of the disposal area. Yearly spring disposal in the same limited area conceivably could eliminate selected food sources within that area. However, this does not appear to be a critical problem for the perch population since most of the eastern section of the Lake Erie Central Basin appears to contain an abundance of both isopods and chironomids, both of which are major food sources for that species.

210. Inasmuch as disposal operations seemed to have little effect on long-term yellow perch feeding behavior, it was considered possible that these fish were captured on the Disposal Site but had fed elsewhere. Stomach analyses indicated that this was not the case. Stomachs from Disposal Areas contained detrital items not present at the Reference Site. Some of these items were undoubtedly from the disposal of dredged material. These include bunker oil, slag, and asphalt. Others such as leaf litter, stones, wood chips, etc., may be available at all sites due to drift, but these appeared only at the Disposal Site with regularity.

211. Obviously, fish captured in the Disposal Area were feeding there, although perhaps primarily on the fringes of the Disposal Site. This seems logical since chironomids and isopods were unavailable near the center of the Disposal Area. These two taxa were present in stomachs along with disposal detritus. It would appear that feeding occurs near the disposed material and probably

less often on the disposal pile.

212. The only major effect of disposal observed during the course of this study was that of egg mortality at and in the vicinity of the Disposal Site. Studies of this impact were conducted only with a minimal effort during 1977 since this was not originally part of the study design. One hundred percent mortality occurred within 250 m of the disposal and may indicate considerable egg mortality in a normal disposal operation from moving dredges disposing over a larger area.

213. The exact cause of mortality is unknown. It may be due to suffocation from burial in fine silts, toxicity from contact with polluted sediments, toxicity from resuspension of materials from dredged material, oxygen deficiency in bottom interstitial waters from oxygen demands, or a combination of these factors.

214. The total extent of mortality from disposal is unknown since no experimental egg chambers were placed at distances between 300 to 1600 m from the Disposal Site. Eggs at the Reference Site, F8 and F28, exhibited a high rate of survival (70 to 100%), thus demonstrating that the effect of disposal is contained within an area less than a circular mile.

215. Most species of fishes present in the Ashtabula area spawn in the previously described "nearshore zone". Therefore, it is unlikely that any major negative effect would occur to them from a disposal at the 50-ft. contour. A few species, however, appear to spawn primarily in nearshore waters and partially in offshore waters. These species spawn over or among gravelly, sandy, or rocky areas which might be present in offshore disposal areas. However, since disposal normally occurs in predetermined areas year after year, and since impact seems to be limited to a radius of $<$ 1600 m, the impact on the total population would probably be minimal.

216. The impact of disposal on other aspects related to the fishery were either nonexistent or of very short duration. No change could be documented in the abundances, growth rate, or

age structure of the yellow perch, smelt, gizzardshad, or drum that were not within normal variation in Lake Erie. Since populations of these species are highly mobile and probably homogeneous in the offshore areas, this result was not surprising.

Chemical Studies

Pelagic Chemistry

217. Predisposal 1975 indicated the impacts that seiches, upwelling, and thermal stratification can have on the chemistry as well as physical variables of the water column. When unstratified, as was the case in July 1975, variables tended to be fairly uniform with depth. However, when stratified, as was the condition during the 1975 disposal, there would be marked differences between the surface (taken 1 m below the surface) and bottom (taken 1 m above the bottom) conditions. The values observed over the entire study area at the Reference Sites and at the Disposal Site prior to August 1975 were similar to those reported for the Lake Erie Central Basin (Sweeney 1971).

218. During the 1975 disposal event, simultaneous collections were made from boats anchored downcurrent of the buoy at which disposal was supposed to occur at Sites D2 and D8. However, in each instance only the vessel within 50 m of the buoy secured a limited number of samples of what was believed to be the dredged material disposal plume. Due to the relatively few reliable samples, it was decided to redesign the monitoring during disposal effort for use in 1976.

219. Immediately after disposal ceased on 14 August 1975, statistically significant higher concentrations of SiO_2, TKN, Mn, and silicates were observed in the water column just above the bottom in the Disposal Site. P_T, DOC, and NH_3-N were lower at the Disposal Areas. The latter may have been a result of adsorption onto settling particulates. The dissolved oxygen also was depressed by 0.4-0.6 mg/ℓ above the mound, a condition that persisted until

after 20 August. Short-term elevated phosphorus levels were observed in the water column following the disposal of dredged materials at a site in Lake Erie off Port Stanley (Sly 1977). However, the results were much more variable with respect to the depth at which the maximum concentrations were observed in contrast to the 1976-77 Ashtabula results.

220. During the 19-20 August sampling, the above-noted chemical and physical conditions persisted with the exception of the phosphorus levels that were similar to the levels measured in the Reference Site. Also, soluble Fe and Zn concentrations appeared to be elevated.

221. The September, October, and November 1975 as well as April and May 1976 collections revealed no statistically significant difference between the water quality above the Disposal and Reference Sites.

222. There was a slight increase in the Mn and decrease in the DO and pH levels just above the bottom at the 1975 Disposal Sites on 10-11 June 1976. Subsequent water monitoring in the 1975 Disposal Areas did not reveal any significant differences in contrast to the conditions at the Reference Site. Biggs (1970) observed a short-lived oxygen decline of 1 mg O_2/ℓ (from 10 to 9 mg O_2/ℓ) within the plume from disposal of dredged material in Chesapeake Bay.

223. The continuous monitoring of the water from depths of 1, 14, or 16 and 17 m below the surface on 24-26 May 1976 while the Hoffman repeatedly deposited dredged materials within 200 m of the anchored Dambach revealed numerous short-lived (not generally) evident 45 mins. after disposal) increases in numerous variables. These included increases in turbidity, total suspended solids, POC, NH_3-N, PO_4-P, P_T, silica, Hg, Mn, and Zn. The pH was decreased but also returned to ambient levels. Oxygen, after an initial slight increase, decreased by between 0.2 to 0.6 mg O_2/ℓ. The above changes, probably due to entrained ambient water or a disposal "slug", generally were more pronounced at the deepest monitoring depth. Also these chemical and physical changes usually were observed to occur in a single short-lived (up to 10 mins.) peak per variable. Exceptions included NH_3-N, PO_4-P, Fe, Hg, and

Mn. The heavy metals patterns tended to be bimodal. This is in agreement with a bimodal release of Hg from dredged material that was observed by Lindberg and Harriss (1977).

224. Select heavy metals also exhibited the largest changes relative to background concentrations. For example, Mn increased from less than 1.0 μg Mn/ℓ (the detection limit) to over 100 μg Mn/ℓ, Fe increased from approximately 10 μg Fe/ℓ to 880 μg Fe/ℓ, and Hg increased from less than 1.0 μg Hg/ℓ to 1700 μg Hg/ℓ. These changes represent the maximum increases for soluble metal concentrations observed during 12 discharge operations in May 1976. The elevated concentrations due to dredged material disposal operations persisted less than ten minutes.

225. An unusual result noted during the field monitoring effort was the high concentrations detected in less than five percent of the samples. This result is unusual because other contaminants such as zinc, that are often found in association with Hg, and more prevalent and highly soluble metals such as Mn did not increase to the same extent in the water column. Also, there were no concurrent increases in parameters such as chloride or dissolved organic carbon that can act as positive analytical interferences in the Hg procedure. A further peculiarity is that the high Hg concentrations in Disposal Site samples that include some dilution due to mixing exceeded Hg concentrations in the interstitial water and standard elutriates prepared with Ashtabula sediments. However, the sediments analyzed for interstitial water and used to prepared standard elutriates were not obtained from the dredged material that produced the high mercury concentrations at the Disposal Site. While all the high Hg concentrations occurred on the same day, suggesting the possibility that unusually heavily contaminated sediments from a limited area in Ashtabula Harbor may be the source, there is no completely satisfactory explanation at this time for the anomolously high Hg levels that were observed.

226. Contrasting the time necessary for a quantity peak to reach the Dambach and the Welch, a second anchored vessel, it was calculated that suspended solids were settling at a rate of 22 mg/ℓ/m from a point of disposal. It also appeared that most of the dredge load dropped in a fairly continuous mass from the hoppers. Perhaps the multinodal peaks

for some parameters were a consequence of aftershock from the dredged materials striking the bottom.

227. Dispersion of the turbidity plume displayed a hyperbolic rate of change with distance. The area most notably influenced by the disposal activity was within 175 m of the point of release. Both area and duration of impact were extended when the dredge was overflowing. The cause for this increased effect was attributed to grain size. When the overflow technique is employed, the material in the hopper has a larger average size which creates a a larger shock wave when it strikes the Lake bottom.

Sediment-Water Interface

228. During predisposal there was no statistical difference between the sediment-water interface values observed in the Reference and Disposal Sites.

229. The results from the 5- and 30-day samplings indicated that only the sediment-water interfaces at the center NDS stations (SD4, SD5, SD6, SD7, SD10, SD11, and SD14) were directly impacted by dredged materials. These locations correspond with the path of the hopper dredge through the Disposal Site. NH_3-N, PO_4-P, Mn, Zn, and Fe were higher while the DO and TOC were lower than observed at the Reference Site.

230. Interface water values indicated that the dredged material appeared to move via erosion in a northwest direction relative to NDS.

Elutriate Chemistry

231. Using the 10-fold dilution of elutriate results in contrast with the values in the open-Lake area, the values for TKN, NH_3-N, and Mn from the 1975 River and Harbor elutriates exceeded the suggested guidelines. Using sediment from the area that was dredged in 1976, guidelines for NH_3-N and Mn levels were exceeded as were those for Fe. It should be noted that the Elutriate Test is not a standard for stipulating whether or not material can be disposed in open water but merely an attempt to ascertain the possible chemical responses that may occur in the field when dredgings are placed in an aquatic environment. Brannon et al. (1976) previously demonstrated that

no relationship existed between trace concentrations of Mn, Ni, Zn, and Cd in the standard elutriate and the total concentration of these metals in sediment. However, there were positive relationships between elutriate heavy metal results and the values in the mobile phase (i.e. interstitial water).

232. Contrasting the field observation with the results of the Elutriate Test, it was evident that the latter did not show the extent of the PO_4-P release which occurred during the 1976 disposal operations. Possibly additional studies should be undertaken to modify the existing and/or develop a new elutriate monitoring procedure in order to better characterize the potential impact of material to be dredged in terms of possible phosphorus enrichment.

233. Using the Elutriate Test data, an attempt was made to calculate whether or not there was adequate water depth in the designated disposal area to dilute the dissolved components in the dredging to "acceptable" levels. The computed results based on the Elutriate Test yielded a much smaller water area than was observed in the field for dilution to less than one-tenth of the results from the Elutriate Test.

Interstitial Water Chemistry

234. The data as well as the results of discriminant analyses for the 1975 and 1976 interstitial water chemistry results suggested that the overall effect of deposition was only detectable during a short time period after the conclusion of disposal operations. These results also implied that the system returned to predisposal interstitial water levels between 30 and 90 days in the second section of the cores and within approximately 90 days in the first section of the cores. No distinct patterns or shifts in areas of impact were ascertained. It was believed that the changes in the interstitial water concentrations were primarily a function of the reestablishment of equilibria within the sediment-interstitial water system. These findings indicated that the original sediment, upon which dredged material was deposited, would have undergone only minimal changes in concentration within the interstitial waters of

that original sediment. Subsequently, if the dredged material was removed via erosion, which appeared to have occurred at Ash-

that original sediment. Subsequently, if the dredged materials were removed via erosion, which appeared to have occurred at Ashtabula, the interstitial water chemistry in the original sediment just below the sediment-water interface would be quite similar to predeposition conditions.

Sediment Chemistry

235. Generally, it can be said that the most apparent effects of disposal were seen in the sediment environment. It also was found that this matrix was the most complex and difficult with which to work, particularly in light of initial lack of comparability between the Reference and Disposal Site stations prior to disposal. For that reason more emphasis was placed on relative changes at each station between samplings. It also should be noted that resuspension and settling of the indigenous sediment atop the released dredge material caused variation in the observations from station to station. Therefore, the following was the general pattern.

236. The percent of water in the 1975 and 1976 Disposal Site cores decreased, particularly in the upper 5 cm, immediately after dredged material was released. By the July 1975 survey, the percent of water in the 1975 Disposal Sites had returned to the predisposal levels. Similar initial changes occurred at the 1976 Disposal Site. It was believed that the return to predisposal levels was more of a function of erosion of the deposited sediment than a gradual increase in the water content and/or compaction.

237. TOC levels decreased sharply after Harbor materials disposal and gradually returned at the 1975 Disposal Site to predisposal quantities. The 1975 River dredgings exhibited the opposite impact, an increase followed by a gradual return to predisposal levels. The material deposited in 1976 exhibited a pattern similar to the 1975 River dredgings.

238. The P_T and total organic nitrogen (TON) content of the

surface sediment in the Disposal areas increased markedly after disposal in 1975 and 1976. Cation exchange capacity (CEC), Cd, Cu, Fe, Mn, Ni, Pb, and Zn showed the opposite changes. The Hg concentration in the River dredgings was higher than that in the indigenous Lake sediment, while the quantity of this heavy metal in the Harbor materials was less than that in the Lake bottom. However, in both 1975 and 1976 there appeared to be a release of approximately 0.5 μg Hg per gram of dredged material during disposal. The observed loss of Hg from the dredged material possibly could have accounted for the increased concentrations of Hg in the water column that were observed during some of the continuous monitoring of the dredging activities.

239. Based on chemical differences between the deposited dredged material and the underlying indigenous sediment, a volume of 15,000 m^3 of dredged material was present at NDS in September of 1976. A contour map based on survey rod and sediment trap data exhibited the same basic distribution of dredged material immediately after disposal with a volume of 18,000 m^3. The apparent decrease of 3000 m^3 between June and September can be accounted for if the sum of erosion and/or compaction processes averaged between 2 and 3 cm over the entire area. Assuming that near the center of the mound compaction alone could have reduced the height of the mound as much as 5 cm, this apparent loss of dredged material is believed to have been probable.

Grain-Size Distribution

240. As noted in the section of this report dealing with the Physical Studies, the indigenous Lake bottom material was not well sorted but heterogeneous in composition. Most of the areas were classified as silty sands or sandy silts. The River material tended to have a higher silt content while the Harbor bottom had more sand than the Lake sediment. It was evident from the particle sizing that when the dredged material impacted the bottom, Lake sediment sometimes would be resuspended or become redeposited atop the adjacent bottom materials. Without this recognition, it would have been difficult to interpret the sediment chemistry results.

241. Particle-size data from the 1976 collections at NDS were plotted on the sampling grid, and contours were constructed in an attempt to illustrate more fully the effects of the deposition of dredged materials. The results for first and second section core data are presented in Figures 18 and 19, respectively. These illustrations indicate that there was a complex set of forces affecting the sediments, both during and after disposal operations. The major change, however, as evident in these illustrations, was due to disposal itself. It was found that the dredged materials contained various-sized particles. It was believed that these materials essentially fell as a single mass at NDS during each individual disposal. It also was reasoned that the dredged material mixed with the original Lake sediments. The end result was a surface layer of essentially all dredged materials, an intermediate area of mixed sediments, and the original Lake sediments. The physical impact of each single mass of dredged material striking the Lake bottom created extreme bottom currents that pushed quantities of the original Lake bottom materials from the center of the Disposal Area to peripheral areas of the study site. The mixing and induced currents, as a result of disposal operations, produced textural changes in the area. Changes with time after deposition, contributing to the variations in grain-size distribution, were believed to be primarily a function of compaction and/or erosion. As a consequence of these two naturally occurring forces, the composition of the sediments at the Disposal Sites appeared to be approaching those found prior to the disposal operations. The particle-size data suggested that, in time, there would be little distinction between the sediments in the Disposal Site and those in the surrounding areas.

Sediment Oxygen Demand

242. Diver-placed SOD measuring chambers used in 1976 yielded results that indicated that the oxygen demand (1.26 g O_2/m^2/day) of the sediment at NDS following disposal was three to five times higher than the levels at the Reference Site. The demand decreased with time.

243. When contrasted with the oxygen content of the Lake Erie

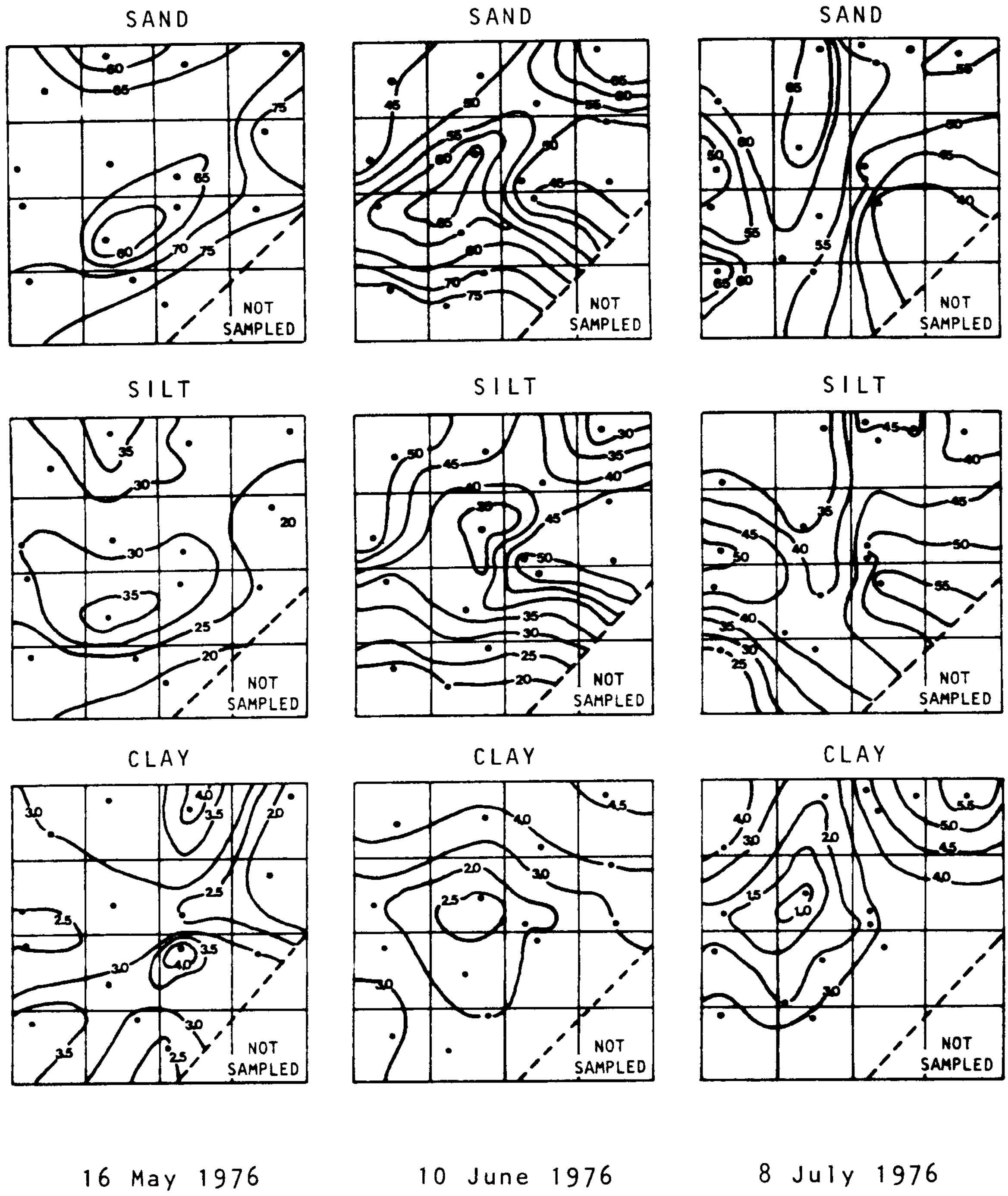


Figure 18. Total percent sand, silt and clay in the first section sediment cores from collections at the NDS area taken during predisposal (16 May), 5-day postdisposal (10 June) and 30-day postdisposal (8 July), 1976

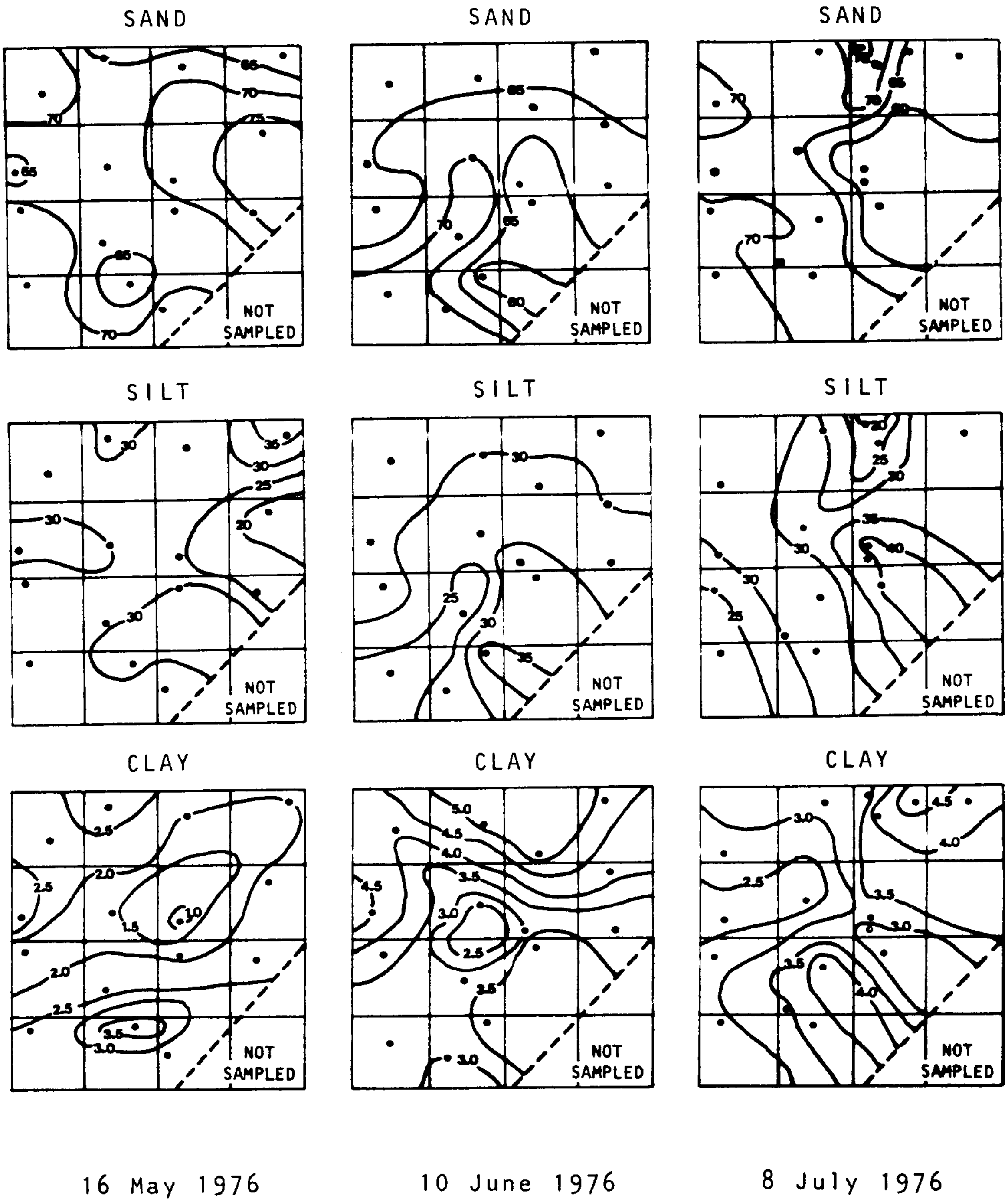


Figure 19. Total percent sand, silt and clay in the second section sediment cores from collections at the NDS area taken during predisposal (16 May), 5-day postdisposal (10 June) and 30-day postdisposal (8 July), 1976

hypolimnion, which can range from 12 to 300 kg O_2, the Ashtabula disposal could remove 0.14% of the dissolved oxygen. Whether localized larger impacts could occur as a consequence of stagnation of overlying waters is a matter of speculation. However, such periods of no current activity in the nearshore area of the Lake Erie Central Basin are most unusual.

Heavy Metals in Fish

244. Heavy metal content in the fish captured in the study area appeared to be more positively correlated with the weight of the fish than to species, feeding habit, or time and location of capture. Relative concentrations of the metals in the fish were the same as those in the sediment: Fe > Zn > Mn > Cu > Cd. Hg in some fish was observed in concentrations exceeding the maximum permissible level of 0.5 mg/kg established by the U. S. Food and Drug Administration. However, there was no apparent connection between the above and the Hg release during disposal.

Heavy Metals and Benthic Macroinvertebrates

245. The relatively small quantity of organisms available in contrast to the amounts needed to perform the analyses necessitated the results being expressed on a "wet" weight basis. Therefore, precautions should be made when comparing these metal-benthic data in Appendix A to other bulk sediment data from this and/or other studies in which results are reported on a "dry" weight basis.

246. Oligochaeta analyzed for Fe, Mn, Zn, Cu, Cd, and Hg showed apparent decreases in metals concentrations after the disposal operations. These decreases, which were statistically significant during one or both of the postdisposal samplings for Cd, Cu, Zn, and Fe, were believed to be primarily a function of the transfer of organisms from the River Dredged Sites to the Disposal Sites. These organisms exhibited significantly lower concentrations of the above metals than were measured in the indigenous Lake organisms.

247. These data did not reveal any accelerated uptake of metals by Oligochaeta as a consequence of disposal. This is not to say there was a similar or different impact on other benthic species since no

other taxa were closely studied. Also, it could not be verified whether the lower concentrations found in the organisms from the postdisposal collections were the result of the River organisms being carried out by the dredge, indigenous Lake benthic forms that migrated through the disposal materials, and/or other Lake benthos which recolonized the Disposal Area. In each of the latter cases, the lower metal concentrations could have resulted if the heavy metals in the tissues of indigenous Lake organisms reached an equilibrium with the lower sediment metal concentrations in the deposited sediments and/or if the organisms recolonizing the area had lower concentrations of these metals.

248. These data also suggest that the order of magnitude of metals content (Fe > Zn > Mn > Cu > Cd) appears to be the same for each of the different taxa of "mean" weight. The same basic order of concentration, except for an inversion of Zn and Mn, was found in the surrounding sediment (Fe > Mn > Zn > Cu > Cd). Uptake of metals by the organisms (based on the above orders) appears to be more a function of availability rather than selectivity. However, the relatively low Mn concentrations along with the proportionately lower Fe concentrations in the organisms relative to the sediment seems to indicate that the presence of factors other than bioaccumulation may be involved.

Chemical-Physical-Biological Correlation

249. Chemical and physical variables were correlated with changes in the biota in an attempt to ascertain cause and effect relationships. However, multiple regression analysis failed to yeild any consistent positive or negative impact between any single physical or chemical variable and an observed biological response. Therefore, it wa concluded that the biological changes that were observed probably were the consequence of the interaction of many factors rather than a response to a limited number of variables.

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